

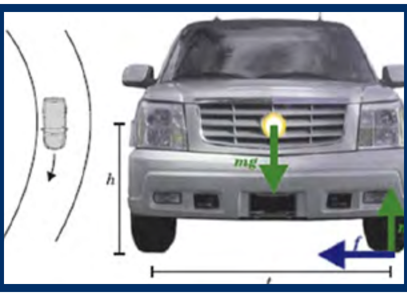
SCIENCE EDUCATION & CIVIC ENGAGEMENT

AN INTERNATIONAL JOURNAL

Volume 4

Issue 1

Winter 2012





Science Education and Civic Engagement: An International Journal
Volume 4: Issue 1, Winter 2012

Publisher
Wm. David Burns

Editors
Trace Jordan
Eliza Reilly

Managing Editor
Marcy Dubroff

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

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

Contents

From the Editors

We are pleased to announce the Winter 2012 issue of *Science Education and Civic Engagement: An International Journal*. This is one of our largest issues to date, which reflects the growth of high-quality scholarly work on teaching science within the context of important social and civic issues.

This issue opens with Part 2 of a **Teaching and Learning** essay by Wm. David Burns, Executive Director of the National Center for Science and Civic Engagement at Harrisburg University, PA (Part 1 of this article was published in the Summer 2011 issue). Reflecting on his experiences as the longstanding Principal Investigator of SENCER (Science Education for New Civic Engagements and Responsibilities), David shares his insights about "lessons learned" from the first 10 years of the SENCER project.

A **Point of View** contribution comes from Orianna Carter (Ohio University Southern), who discusses the opportunities and challenges of teaching science at a rural campus in Appalachia.

In the **Research Article** section, Janice Ballou (an independent consultant) presents extensive survey data about how faculty teaching and their perspectives on students have been affected by the participation in the SENCER project. Her analysis of these data shows a widespread impact of professional development activities such as the SENCER Summer Institute.

In the journal section on **Science Education and Public Policy**, Joseph Karlesky (Franklin & Marshall College) contributes a thought-provoking article on how the use of scientific evidence to make public policy decisions is influenced by contested political interests. He proposes that science education would benefit from being more cognizant of how scientific information can be promoted, manipulated, or rejected during the political process.

We are pleased to have a broad selection of **Project Reports** that span a range of topics, including mathematics, public health, water quality, environmental science, and traffic analysis. Michael Berger (Simmons College), Jack Duggan (Wentworth Institute of Technology) and Ellen E. Faszewski (Wheelock College) discuss a collaborative curriculum project called The Environmental Forum, which promotes, community-building, and service-learning throughout the Colleges of the Fenway, located outside of Boston. The "trans-disciplinary" challenge of traffic issues in Los Angeles is tackled by an appropriately interdisciplinary team. This project has been developed by a group of faculty from Woodbury University–Nageswar Rao Chekuri, Zelda Gilbert and Marty Tippens, who have partnered with Ken Johnson (City of Burbank) and Anil Kantak (Jet Propulsion Laboratory). Another example of interdisciplinary synergy is provided by Umi Ghosh-Dastidar and Liana Tsenova, both from the New York City College of Technology, who describe a project called Bio-Math Mapping. This project introduced mathematics and computer science students to the techniques of water quality analysis and applied them to two New York City waterways. After collecting authentic scientific data, students applied their knowledge of statistics to determine the risk from disease-causing and drug-resistant bacteria.

Reem Jafaar (LaGuardia Community College) provides a mathematics teaching module based on the serious problem of student debt, which is now attracting widespread national attention. Kathleen FitzPatrick (Merrimack College) describes course that is organized around contemporary health issues (immunization, obesity, immunization, etc.) and links these themes to service-learning projects. SALG-based assessment data of student learning gains reveals that the course design promoted improved understanding of the interplay between science and civic issues, in addition to other documented gain. The final project report is a contribution from a faculty team at Indiana State University—Peter J. Rosene, M. Ross Alexander, and James H. Speer—who describe the implementation and assessment of the SENCER educational model within the introductory laboratory courses in the natural sciences. They evaluate how the change in educational approach affected student's perceptions of teaching effectiveness in comparison to a more traditional curriculum.

In conclusion, we wish to express our thanks to all the authors who have contributed to this issue of the journal.

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

From the Publisher

Every once in a while, we are lucky enough to meet and work with someone who not only seems to "get" what we think we are thinking or saying, but is so gifted—and possesses so subtle and gentle an approach—that they actually improve upon our best thoughts and actualize what, in truth, we had only imagined we were trying to say. That's what great authors and artists do. It's also what great graphic designers do. John Svatek was such a designer.

Broadly educated and artistically accomplished, John was also a deep and creative thinker, a devoted and doggedly-patient collaborator, an efficient and effective manager and producer of results, and a cheerful "envisioner" and "revisioner" of images, graphics, and messages, of signs in general. He was, in the tradition of Roland Barthes, intellectually engaged, at the deepest level, with thinking about how meanings are made. It was, therefore, both a shock and a tragic loss when John died suddenly last September at age 49 of a brain aneurism. We mourn his death today and celebrate his life by calling attention to his great contributions to our work.

This Journal—and the National Center that sponsors it, as well as the SENCER program, which brings to life the ideals of the Center—benefitted from John's talents. He revised this website, chose the fonts, styles, and graphics, laid out the articles all while working, as so many designers have to do, with some "givens" that he might not have chosen himself had he been able to do the design from scratch. He did this with his customary effectiveness and good humor. That wry humor emerges in the little promotional piece he did for the Journal—check out the book titles.

His vision of our Center's SENCER work, as connected and overlapping waves of communication, you could say, is reflected in the "chop" or logo like design he chose for SENCER, when, working with his long-time collaborator and dear friend, Marcy Dubroff, SECEIJ's managing editor, he designed and developed the SENCER viewbook.

John Svatek

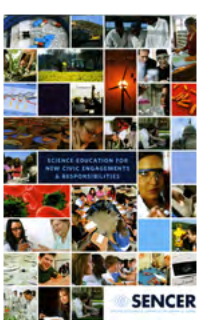
Our Center, this Journal and our projects have never been in a position—financially or morally—to spend much money on marketing. When given a choice on how to spend the grant or donor funds with which we have been entrusted, we have always opted for programs and service over promotion. This has the unfortunate effect of limiting our dissemination efforts and, in some ways, making our "stuff" (website, materials, etc) look a little dated. John helped us overcome these conditions.

Conscious of our frugality but convinced of the value of what we do, John shepherded us to develop more effective and attractive materials, ones that convey our values and our purposes. He helped us become better at what we thought we were doing—and better at what we really do—than we could have without him.

Francis Bacon wrote: "…I think a painter may make a better face than ever was; but he must do it by a kind of felicity (as a musician that maketh an excellent air in music), and not by rule." John possessed "a kind of felicity" and he helped us and many other clients "make a better face than ever was." We shall miss him and we extend our condolences to his family and friends who were fortunate to know him longer and better than we did.

—*Wm. David Burns*
November 2011

SENCER
APPLYING THE SCIENCE OF LEARNING TO THE LEARNING OF SCIENCE



TEACHING AND LEARNING

"But You Needed Me"

Reflections on the Premises, Purposes, Lessons Learned, and Ethos of SENCER PART 2

Wm. David Burns
Publisher, Science Education & Civic Engagement—An International Journal

This paper is based on the opening plenary address at the 10th annual SENCER Summer Institute delivered by SENCER's co-founder, the paper's author. SENCER (Science Education for New Civic Engagements and Responsibilities), supported by the National Science Foundation, works to improve learning and strengthen civic engagement in undergraduate courses that teach through complex, capacious, unsolved civic issues to canonical knowledge and practice in STEM and other fields. Part one appeared in the last issue.

Introduction

In part one of this paper, I described the origin of the SENCER project and discussed some of the connections between scientific and democratic practice. Serving as the principal investigator of the SENCER project over the past 10 years has given me the opportunity to work with a vibrant and diverse community of scholars, administrators, students and researchers who represent, as we in the national office say as often as we can, the intellectual capital of our work. Over these years, much good has come from the efforts of these scholars who have been engaged in connecting the science of learning to the learning of science, as we try to do in the SENCER project. It has been my distinct privilege to observe the good that can come—as well as some collateral issues that emerge–when this work is undertaken. So on this 10th anniversary of SENCER, I offer an abbreviated and highly personal list of some of the things I have learned from my work with our National Center for Science and Civic Engagement and the SENCER community.

Lessons Learned

Here are seven lessons that I submit for your consideration:

1. Teaching gets "transformed" through SENCER participation, not just courses.

We began the SENCER project focused on the non-STEM major where change was possible because, frankly, it seemed like almost nobody in power (except deans, who were worried about STEM education and so called "student apathy") really cared very much about the non-major. We used to say that when you saw the science float, you could be pretty sure the "gen ed" reform parade was just about over. The so-called non-major was neglected.

We chose the non-major as the target of our efforts and we proposed interventions at the course level—that basic building block and unit of academic currency. It's not that there were no champions of the approach we were advocating. There were plenty of brave pioneers, and they flocked to our program, in part because, until we created it, they were like dozens of John the Baptists, voices crying in the wilderness.

Indeed, I even coined a DSM-III[1] term for the condition we observed. I called it VDD—validation deficit disorder. It seemed like a pretty curable condition: to recover you only had to discover that other smart folks thought there was something less than ideal about how science and math were being taught in college.

With the help of some wonderful colleagues, we set about creating courses, course intersections, and learning communities, and "SENCERized" parts of courses. While this was happening the people doing it began to realize that they were changing as well. They were more engaged, they were more interested. They were remembering what they knew about learning, but had somehow forgotten. They were changing their notions about student capacity and ability. Most important, they were reminded about why they got into teaching in the first place.

The biggest implication here is that the SENCER ideals don't stay confined to the courses for non-majors. Once you start teaching this new way, you start wanting to teach this way in all the teaching you do, so we observe the migration, slow to be sure, from the margins closer to what some observe as the main mission, majors.

I think this migration is spurred by changes in pedagogy and successes that come from the different kind of political community that a classroom becomes when failure is no longer mistaken for rigor and disengagement is not attributed solely to defects in the person accused of apathy and indifference.

So the lesson I want to offer is: **get ready to experience changes in yourself as a teacher as you change your courses and programs to attune them to matters that are real, relevant and of vital interest to citizens in a democracy.**

2. Less may not always be more, but more is almost always less.

Folks trying to reform STEM education wrestle with the content versus context question. The fear is that if you take the time to establish "why" learning matters, you'll sacrifice some of the "what" that has to be learned.

In my observations at least, this has proved to be more theoretically than practically correct. No less an eminent cognitive scientist, Father Guido Sarducci, who has made video appearances at SENCER Summer Institutes courtesy of John Bransford, has lectured us on "the five-minute university"—hilariously reductive and dangerously close to being true. [2] Yet some of us persist in believing that this hyper-reductiveness is not what happens in the lives and minds of our own students after they take our courses. And we sometimes believe this even though we are not prepared to risk testing students on materials we "covered" that were assessed in a prior examination.

Rather than try to talk the doubters into believing as I do on this topic, may I propose an experiment? See if what is "left"—what is available intellectually as knowledge, or skill, or inclination, or attitude—at the end of a course, the residuum, is greater in the instances where pared but higher level expectations were clear, active pedagogies were employed, and real issues framed the academic experience. Design an experiment to test this. When students get the main points, the big picture, the dimensions of what Ellen Goldey and Byron McCane call the really big questions or what Rick Duschl and company have identified as the four strands[3], are they both better equipped and more likely to get the stray or new content on their own? Moreover, do they have what we might call intrinsic desires to do so? I think the answer is yes for the most part. See what you find out.

---

1 The allusion in this jocular reference is to the *Diagnostic and Statistical Manual of Mental Disorders*, published by the American Psychiatric Association; DSM-III was the version originally brought out in 1980.

2 See: http://www.youtube.com/watch?v=kO8x8eoU3L4

3 For a discussion of the "four strands" see: *Taking science to school: learning and teaching science in grades K-8* (Richard Alan Duschl, Heidi A. Schweingruber, Andrew W. Shouse, National Research Council, 2007. "Really Big Questions" is a title Ellen Goldey and Byron McCane have given to large trans-disciplinary matters. Here's how they described them in their session at SSI 2010: "Big problems and polarizing conflicts do not have single-discipline solutions but instead require critical reflection and purposeful integration of multiple perspectives. Therefore, we must do a better job of modeling for our students what it means to take an intellectually sophisticated approach to 'really big questions' (RBQs). Only a citizenry that respects scholarship, is accustomed to ambiguity, and engages with complexity can identify and act on solutions to society's capacious problems. The workshop leaders (a biologist and an archaeologist/religion professor) will briefly overview how interdisciplinary programs have engaged our colleagues and students in contemplating RBQs, such as that of human origins. Participants will brainstorm polarizing views of this RBQ as reflected in the popular media, contrast such dualistic views with higher-order levels of intellectual development (Perry, 1970), and demonstrate how we can construct new knowledge through the integration of different fields of scholarship."

It is difficult to underestimate the importance of having clear learning goals in connection with producing the results you want. As textbooks grow longer and attention spans grow shorter, this planning work becomes even more critical. Beyond goals, matching of aims with the right pedagogies is critical. Assessments, too, should be tailored to both course goals and corporate aims that the course seeks to advance. [4]

The lesson I've learned: **It helps to think really hard about the learning that you think really matters and connect that learning to things that really matter to the learners.** See for yourself if the results aren't better than those that come from one current approach that I liken to opening the fire hose of 10,000 facts, training it on the students, and hoping that they don't dry off entirely by the time the next semester begins.

A coda: where you are not in control of what is expected in a course, find ways to engage people at the policy level who are, so that you can help influence the conditions that give rise to the broken pedagogies in the first place, be they exams (like Advanced Placement tests), the expectations of accreditation bodies, transfer considerations, etc. In short, engage.

3. People do need people because change is socially mediated.

It is true that people learn differently (there is a whole industry dedicated to propagating this notion). It is also true that most of what we need to know about how to make learning better is already known, published, and available in several dozen reports, a few of the better ones written by Jay Labov, Stephanie Knight, Elaine Seymour, John Bransford, Jose Mestre, Rick Duschl and other folks who have been kind enough to lend their intellectual gifts to our SENCER efforts over the years.

The reports are great, like our models, our extensive and quite wonderful digital library, and lots of other useful assets. All too often, however, they remain un-accessed. "Women come and go, talking of Michelangelo" as T.S. Eliot wrote in Prufrock. Perhaps so, but, borrowing from a source that I am afraid remains unknown to me, how many of us believe that "Scholars come and go, talking of Cross and Angelo"? [5]

What seems to change this—what gets Cross and Angelo and lots of other valuable assets off the shelf and into practice—is face-to-face experience, time for conversation, live demonstrations, and the formation of groups who share similar concerns, aspirations and goals. People open the doors to these other resources to one another. That is why our Institutes have proved so valuable over the years. It is why we invest resources in efforts to keep people connected. It is why we indulge in what starts as a useful fiction of creating teams to attend our institutes, because sometimes teams really work and that makes all the difference. [6]

The lesson I've learned is this: **Working together face-to-face is vital, hard as it is to find the time these days.** Once you've met face-to-face, you can call upon colleagues to help. Creating and sustaining a community of practice[7] is entirely within our capacity and is necessary to achieving larger scale reforms.

4. Change takes time, but time flies.

When Karen and I started this project we were woefully wrong about just how much time it would take for even enthusiastic colleagues with the power and resources to do so to make the kinds of changes we envisioned. Sure, there were notable examples—UNC-Asheville being one where very major campus-wide changes actually happened within a relatively brief period of time. But, for the most part, the kind of course-level and learning-community-level change took more than the year or year and a half that we had originally envisioned. The good news is that the changes brought about by SENCER faculty members have been remarkably durable (some 90% of created courses having entered the permanent curriculum.)[8] We may have sacrificed speed for durability, a

4 By corporate aims, I mean the goals the institution has for student learning outcomes, such things as developing critical thinking skills, effectively communicating, being capable of evaluating claims made numerically or statistically—the kinds of overall outcomes that are not specific to only one course but are expected to be developed in most courses.

5 T. S. Eliot's *Prufrock and Other Observations* (1917). Cross and Angelo refers to the important book, *Classroom Assessment Techniques: A Handbook for College Teachers* (Jossey Bass, 1993) by Thomas A. Angelo and K. Patricia Cross.

6 Respondents who had attended more national SENCER events were significantly more likely to assert that SENCER participation had improved their perception of student ability to engage in critical thinking, problem solving and to collaborate and engage in group work. This finding is drawn from a survey of SENCER program participants who attended at least one national or regional workshop between 2001 and 2010. All told, 602 individuals (a response rate of 45%) participated in the 70-item web-based survey conducted between October 13, 2010 and November 30, 2010. From a forthcoming publication by J. Ballou and D. Kraus Tarka.

7 See: Wenger, Etienne. *Communities of Practice: Learning, Meaning, and Identity.* Cambridge: Cambridge University Press, 1998.

8 For program assessment data including the findings that "the majority of instructors answering the online survey said their courses would continue into the future (93%) and that their SENCER course was part of the permanent curriculum of their institutions (81%)", see: www.ncsce.net/About/pdfs/ SENCER-EvaluationReport.pdf.

reasonable trade-off. While it took longer for things to happen, it also seems to me that time is just flying by. It may just be my age: a summer doesn't last forever as it did when I was a child.

So where does this leave us? I think the take-home lesson is simple: (1) it will take longer than you think to get things done, and (2) because time is flying, you'll feel like you have less time to try to get things done. **So start now, do something small rather than doing nothing at all, and then build on what you have done. Don't wait to have the perfect course before you teach it. You'll find out how good it is by teaching it.** As Henry Petroski, the eminent engineering professor from Duke, has shown us, form follows failure, not function.[9] So set some short and longer range goals and approach this work as a natural scientist would approach a problem in natural science, improving as you go along depending on what you discover.

5. Student partnerships are keys to success.

This is true at so many levels. I think it is safe to say that the SENCER courses and projects that have been designed with students helping all the way just tend to be better. They are more likely to capture something that truly matters to and interests students. They are more likely to be "advocated for" by students and recommended to other students by students. This is not always the case, but it is generally so.

Engaging students in planning (and delivery) is one anodyne for the pains that can come from the disease of solipsism. You need students to help you find out if your topic is as interesting as you think it is. Creating a "market pull" for courses should be a desired end. You want students not because they have to take your course, but because they want to take your course. Courses and programs that meet both important institutional and student needs and contain opportunities—for community engagement, service learning, internships, research projects and other experiences made possible by progressive pedagogies—are very likely to create this "pull." Students can therefore become the engines for these desired changes and they can help establish some continuity of interest within the student body, where such continuity is currently lacking.

Students can make vital and valuable intellectual contributions to course content and design, development, and refinement. Indeed, I would suggest that a partnership approach will not only improve the course or program being designed and taught, but it will also enable the modeling of collaborative and mutually respectful engagement, while promoting respect for scholarly authority.

The lesson: **It helps to invite students into the planning and delivery process to create opportunities for student leadership and engagement.** Listen to student interests and needs, connect these, as William James earlier instructed us, with your own learning goals "so that the interest, being shed along from point to point, finally suffuses the entire system of objects of thought." [10]

6. Assessment should be integrated with practice.

Too often we suffer from what seems to be an oppressive divorce between pedagogy and assessment. Assessment becomes something that is done to you and is thus to be watched carefully and with some suspicion, sometimes with the "gloomy foreboding" of the butler in *Sullivan's Travels*. After all, you have probably observed that "the evidence on evidence" is not so clear. [11]

Things are assessed unevenly and often not just at the wrong intervals but at the wrong times, as well. Does it really make sense to assess learning in a "final" exam, or should we come back sometime later and ask, how much was, in Bacon's terms, actually "digested"?[12] And can we responsibly wait until a midterm to find out how many students are lost? Terry McGuire once observed that students can get lost in places we never knew existed.[13] It's our responsibility to find out who is lost and to do what we can to repair the situation.

---

9 Henry Petroski, *The Evolution of Useful Things*, New York: Alfred M. Knopf, 1992.

10 William James. *Talks to Teachers on Psychology and to Students on Some of Life's Ideals*. New York: Henry Holt and Company, 1899, pg. 96.

11 See: Elaine Seymour's *Tracking the process of change in U.S. undergraduate education in science, mathematics, engineering, and technology*. Science Education (86): 79-105 and the recent *Determining Progress in Improving Undergraduate STEM Education: The Reformers' Tale* by Elaine Seymour, Kris DeWelde, and Catherine Fry, accessible at www.nae.edu/File.aspx?id=36664

12 See Francis Bacon's *Of Studies*: "Some books are to be tasted, others to be swallowed, and some few to be chewed and digested." Of course, something we could call "digested learning" is what we should strive for, as opposed to the "memorize and dump" that all too many students have become habituated to (and rewarded for) doing.

13 See: *Reinventing Myself as a Professor: The Catalytic Role of* SENCER by Terry McGuire; retrievable at: http://serc.carleton.edu/sencer/backgrounders/reinventing_myself_professor.html.

Then there is the issue of: When we do assessment, are we asking the right questions? [14] Shouldn't the questions emerge from the design of the course or learning experience? Let's measure the right things.

We need to reconnect assessment with pedagogy if for no other reason than to inform and improve our instructional design and delivery (this is a strength of the SALG instrument[15] that we helped to design and the use of which we advocate).

To those of us who rely on multiple sources of information to make our most critical judgments, what students think about their learning and our teaching is essential data, not dispositive perhaps, but surely worth knowing. But it is even more worth knowing if it is derived from some appreciation for what we were actually trying to do. Hence the need for customization of instruments so that they are sensitive and specific to our uses and purposes.

The lesson learned: **It helps to tie assessment to pedagogy (including reflection on course activities like service learning, research, etc); assess frequently and at intervals short enough to enable you to make "repairs" and mid-course corrections; imagine (and try to over-determine) how what you are teaching helps achieve broader institutional goals (that may be assessed later and in other ways).** This is a "citizenship" duty. And to students, I'd like to make a special plea: find ways to let your professors know when you genuinely don't "get" something. This is not an excuse for shirking responsibility, but rather a plea for taking on responsibility for learning.

7. Success matters.

Over the last 10 years, I have been awed by the hard work, the energy, the ingenuity, the good will and the bravery, generosity, and desire for community of the faculty, administrators, community representatives and students that we have been privileged to meet through SENCER. There are exceptions, of course, but they prove the rule.

The single greatest ingredient in the success of the best of the SENCER projects is the degree to which those creating them are genuinely committed to identifying their own success as a teacher with the success of their students. This is not a romantic idea or one that romanticizes students. You know better than I that we are all made of that same crooked timber of humanity that Kant wrote of long ago.[16] Students are too.

But the difference between success and failure seems to lie in part on how engaged the parties to possible success seem to be in the transactions and collaborations that make up the learning experience or, for that matter, the larger civic community. "The medical care was great but the patient died," no longer cuts it in medicine. Finding out why the death occurred and making sure it doesn't happen next time if it doesn't have to becomes the obligation of the physician and all the members of the healthcare team. Our losses in education may not be as profound, but they can be as permanent.

We can no longer tolerate the high casualty rates in our courses, the losses of talent, the unopened doors, the dropouts, the "never-tried-to-begin-withs"—all these things that may have passed as markers for excellence in earlier days. Why? For our economic welfare, of course, but that too seems less convincing: if you can outsource your customer service program, why can't you outsource engineering, actuarial work, basic research, as well?

I think there is a larger and more persuasive answer: If nothing else, this is important because this stuff—the stuff of SENCER courses and the subjects of the work of our colleagues from community and governmental organizations—really matters. And there seems to be more to think about and to do every day. As I mentioned before, our systems are indeed too complex to fail.

So, if I have learned nothing else, it is that we need to change our basic paradigm from one that somehow confuses failure with rigor. Instead **we should measure our success by the success we encourage, enable, and engender.** This means giving something up, or at least temporarily surrendering some of the status you earned through your hard work in a system that seemed to think little about the morality of boiling off the dross in order to come up with the gold. But I think we can recover from this condition—this culture, if you will—though a renewed commitment to both access and

14 Early on, when Karen Oates and I were planning SENCER, we heard over and over again from faculty members we interviewed how disappointed they were that the traditional teacher evaluation "systems" were loaded against innovative pedagogies.

15 The Student Assessment of Learning Gains instrument was originally designed by Elaine Seymour. Its contemporary, web-enabled and NSF-sponsored version can be accessed at www.salgsite.org.

16 Immanuel Kant wrote "Out of the crooked timber of humanity, no straight thing was ever made" in *Idea for a General History with a Cosmopolitan Purpose (1784), Proposition 6*. It was through Isaiah Berlin that I became familiar with Kant's observation. See, among other Berlin works: *The Crooked Timber of Humanity: Chapters in the History of Ideas* (Henry Hardy, ed. Knopf, 1991).

success and though new partnerships with others. As tired as members of the professoriate are from working hard and achieving less than they had hoped to achieve, I know that refreshment comes from the prospect of the success and accomplishment of genuine learning.

Ten years is quite a while and I am sure that on other days and in other circumstances, I would have a different (and much longer) list of the lessons I have learned to share with you, but this is today's. I hope you will find some of what I have noted helpful to you as you plan ahead and work towards better outcomes in STEM learning and renewed civic engagement.

Four Promises and the SENCER Ethos

Over the years, I have been asking colleagues to make promises to one another and to me as we embarked on the work of our Summer Institutes. These Institutes are intensive, multi-day residential "workshops" at which many of participants are meeting one another for the first time. The participants find themselves constituting a little "polity" or political community that is temporary, to be sure, but in a more optimistic scenario, might last longer than the few days to be spent together. My belief is that people who make these kinds of promises—covenants, if you will—with one another will stand a better chance of enlarging the scope of possibility and achieving important goals. The four promises stake out what we might call an ethos for our work. I offer them here because I think they have a general applicability:

Let us promise to work hard to fulfill our obligations to those who are making it possible for us to do the work that we are about to do. In the case of the SENCER Summer Institute, this means, in the first instance, ensuring that the investments made by NSF and our other donors and funders are well spent. But it means more, especially since the NSF is essentially a trustee of funds allocated by Congress. It means being conscious of all the people, the farmers and ranchers, the miners, the folks who own and operate beauty parlors, the bond salesmen, the nurses, the CEOs, indeed everybody who works at things for a living and who pays taxes, or makes charitable donations in lieu of paying taxes, or who supports our work in other ways—like the people who fly the planes that get us to workshops, or clean the rooms we inhabit while we attend them.

Higher education exists because others are paying for it to exist, whether in direct state subsidies, foregone tax income, student aid, and other sources. We owe a lot to the kindness of strangers. We owe it to them to be serious, to be productive, to maintain the trust they have implicitly and often anonymously extended to us.

The second promise will be more challenging than the simple market transaction that a reductive version of the first promise could become:

Let us promise to be moral today. It is so easy to have perfect knowledge of what we would have done in the past. None of us would have participated in the system of chattel slavery. We wouldn't have confused European-borne infectious disease with God's plan for land redistribution. We would have all joined the French resistance, repaired the gas tank on the Pinto, installed back-up systems to close undersea well heads without the benefits of a loss vs. cost projections, even paid more attention to our nuclear power plants.

But what about today? What do we do with the knowledge we have today. Thinking about HIV in Africa is what moved me to work on a project to do what we could to end the curricular silence there.

It similarly has led Sherryl Broverman and some terrific students from Duke and Rose Odhiambo and some terrific students from Egerton University to found a girls school in Kenya.[17] Who would have thought this possible? It is what moved some faculty members and students from Francis Marion University to engage in a public campaign to change policies about health warnings for South Carolina's pole fishermen.[18]

Promising to be moral today is another way of thinking about what obligations come with the knowledge we've been lucky enough, worked hard enough, and been privileged enough to acquire. This, I hasten to add, also applies to our knowledge about teaching and pedagogy. How do we justify maintaining instructional practices that we have evidence produce results that we could not call desirable?

While promising to be moral today is a deeply individual promise, the third promise is especially important in the context of group endeavors, such as our Summer Institute:

17 For more information about the WISER project, see http://wisergirls.org.

18 Hanson, Lynn and Lisa Pike. The mercury problem in South Carolina's freshwaters: a project funded by the Sustainable Universities Initiative. CD-ROM. Florence, South Carolina: Francis Marion University, 2003.

Let us promise to use our power to enlarge what we all know. At our institutes, or at professional meetings, and surely on campus, on any given topic, any one of us could most likely, if we chose to, make it pretty clear how much many of the rest of us don't know. Indeed, we have become so advanced in learning things nobody else knows that we're all quite vulnerable to being found out as people who indeed know very little. So to avoid embarrassment, we've developed a fairly broad set of defenses.

Finding ourselves in these conditions—that is, being among a huge group of people all of whom probably know more than we do about the things they do know about—we have a choice to make. We can use our time together to show what people don't know or we can use our time together *to enlarge what we all know.* Choose the latter, not because you want to avoid the rigor and give and take of a robust critical gaze, but because we can achieve more if we think about what we have to teach and how we can help each other learn. Engaging with complex issues outside our areas of expertise involves risk for scholars; engaging in active pedagogies can also pose risks for students who have performed well in conventional contexts.

Our last promise deals with risk:

Let us promise to encourage intellectual risk but also to act to reduce damage to those who have the courage to take the risks. I added this promise after we started to realize that some very good students were resisting some very good pedagogy. I wrote about this in a piece called "With Friends Like These."[19] In short, we were asking students—especially accomplished students—to come out of the "comfort zones" of their previous patterns of study and knowledge production and take risks that exposed them to harm. Some of these risks were cultural: you can't expect someone from a tradition of deep respect for authority to "challenge" a professor, argue with authority, become Meno to your Socrates, etc. (Malcolm Gladwell uses the Korean airlines crash to make a similar point in the Outliers book.[20]) Other resistance is parsimonious and economical: For students who have mastered the study and memorization techniques that earned them a 4 or 5 on their AP tests, it might be a little risky and even self-destructive for them to try a course where one couldn't memorize the answers because they weren't yet really known.

So we began to pay attention to risk and to the moral obligations, if you will, that come from asking our students, our "friends," to take risks. This also applied to faculty members in our programs who were being asked to avoid the hegemony of the textbook or the security of a "tried and true" syllabus in favor of the "inventiveness by which the one is able to mediate…associations and connections" to recall James once again. So if we are going to encourage intellectual risk, as I believe we must, then what can we do to mitigate the possible harm that can come to those who take the risk?

I suggest just two strategies we can employ to fulfill this last promise. When we discussed this question of risk at a Summer Institute in San Jose, Linda Gonzalves of Stockton University, offered a suggestion: "when I increase risk, I decrease ambiguity." This is easier said than done, but it is worth trying. Its corollary might also be worth thinking about: when I increase ambiguity, I decrease risk. All of this relates to the larger obligation of being as clear and transparent about learning objectives, reasons for assignments and exercises, rationales for what is being learned, and compensatory strategies that provide "second chances" for students who took the risk and didn't do well.

"But You Needed Me"

As I mentioned, taken together, these promises constitute a kind of ethos that guides our work and that could be considered as guiding principles for our democratic engagements with one another, as well. There is another element, a foundational notion, if you will, underlying them that we need identify and think about as we do the very important work of education reform and civic engagement. Permit me to use the words of the author of one of my favorite books, An Intimate History of Humanity, the Oxford historian Theodore Zeldin, to identify this element:

> 'My life is a failure.' Those were the words with which I began this book, and I finish it with the story of a murderer who repeated that phrase many times, until one day…
>
> Half a minute is enough to transform an apparently ordinary person into an object of hatred, an enemy of humanity. He committed a murder and was sentenced to life imprisonment. Then in his desolate jail, half a minute was enough to transform him again, into a hero. He saved a man's life and was pardoned. But when

19 The essay is retrievable at: http://serendip.brynmawr.edu/sci_cult/scienceis/burns.html.

20 Malcolm Gladwell. *Outliers: The Story of Success,* Little, Brown and Company, 2008.

he got home he found his wife living with someone else and his daughter knew nothing of him. He was unwanted, so he decided that he might as well be dead.

His attempt at suicide was also a failure. A monk summoned to his bedside said to him, "Your story is terrifying, but I can do nothing for you. My own family is wealthy, but I gave up my inheritance and I have nothing but debts. I spend everything I have finding homes for the homeless. I can give you nothing. You want to die, and there is nothing to stop you. But before you kill yourself, come and give me a hand. Afterwards, you can do what you like.'

Those words changed the murderer's world. Somebody needed him: at last he was no longer superfluous and disposable. He agreed to help. And the world was never the same again for the monk, who had been feeling overwhelmed by the amount of suffering around him, to which all his efforts were making only a minute difference. The chance encounter with the murderer gave him the idea which was to shape his whole future: faced by a person in distress, he had given him nothing, but asked something from him instead. The murderer later said to the monk: 'If you had given me money, or a room, or a job, I would have restarted my life of crime and killed someone else. But you needed me.' That was how Abbe Pierre's Emmaus movement for the very poor was born, from an encounter of two totally different individuals who lit up a light in each other's heart. These two men were not soul mates in the ordinary, romantic meaning of that word, but each owes the other the sense of direction which guides their life today.

It is in the power of everybody, with a little courage, to hold out a hand to someone different, to listen, and to attempt to increase, even by a tiny amount, the quantity of kindness and humanity in the world. But it is careless to do so without remembering how previous efforts have failed, and how it has never been possible to predict for certain how a human being will behave. History, with its endless procession of passers-by, most of whose encounters have been missed opportunities, has so far been largely a chronicle of ability gone to waste. But next time two people meet, the result could be different. That is the origin of anxiety, but also of hope, and hope is the origin of humanity. [21]

"*But You Needed Me.*" This is the take home message I want to leave with you. We are so accomplished at telling people what they need from us, telling students what they need to learn from us, telling ordinary people that they need to understand science, and so forth. We need to get a lot better at thinking about what part of our project—be it intellectual, pedagogical, political, or theological— we can't do without the contributions that the "objects" of our endeavor can offer. Working together we need to invent ways to enact this reversal of the ordinary approach.

For these reforms to work and indeed for democracy to work, students, colleagues and citizens need to be needed and to feel that they are needed, much like the prisoner discovered himself when he received the greatest gift that the monk could provide (and the monk really needed what the prisoner could offer him as he established his Emmaus project). So the conclusion I reach in thinking about 10 years of encouraging attention to the things that SENCER has focused on is quite simple: We need you. Our democracy needs you. We cannot do the intellectual work we need to do, make the improvements in learning we need to make or build a just society, without you.

About the Author

Wm. David Burns is the founder and principal investigator of SENCER, the NSF-supported national dissemination project. He is also executive director of the National Center for Science and Civic Engagement and professor of general studies at the Harrisburg University of Science and Technology. Prior to establishing the National Center, he served as senior policy director for the Association of American Colleges & Universities (AACU). During his nine years with AACU, he established the CDC-sponsored Program for Health and Higher Education and created the Sumner Symposia dedicated to exploring the power that students have to improve the health of colleges and communities. David is the principal author and editor of *Learning for Our Common Health* and, among other publications, the article, "Knowledge to Make Our Democracy."

21 Theodore Zeldin, *An Intimate History of Humanity* (HarperCollins, 1995),

POINT OF VIEW

Advancing Science Instruction on a Rural Campus

Orianna Carter
Ohio University

Abstract

Teaching science on a small rural campus incurs many challenges, not the least of which is addressing incoming student quality (preparedness, study skills) in the general population. Small colleges and university faculty must be inventive in order to secure equipment and funding to succeed in their scholarship. Unique to rural campus faculty is the necessity to adjust expectations to the region's cultural attitudes toward higher education. This presents yet another barrier toward motivating students to excellence. Can faculty address these challenging issues through applying research skills to meet their professional agenda while also improving the scientific mindset of a small campus community? This article elaborates upon my personal experience tackling local resistance to learning science and evolving perceptions toward my role as an educator and mentor.

Appalachian Medicinals Field Trip

"The only obstacle to discovering the truth is being convinced you already know it."

— Ashleigh Brilliant

To be an effective educator, one should embrace openness to learning. Thus, it is fortunate for me to teach in a discipline where I must constantly keep abreast of new knowledge and advances in technology. Outstanding teachers and mentors, who motivated me through their passion for the study of life, with its myriad levels, nurtured my own enthusiasm for biology: from the miniscule to the magnificent ecosystems. As an educator, my primary motivation is to evoke similar feelings in my students, science majors and non-majors alike, while caring for their intellectual and emotional growth.

To accomplish this goal, I use teaching strategies highlighting interdependency among organisms: integrating the study of plants and animals through examples of symbiotic relationships and shared evolutionary survival strategies. This holistic approach to teaching biology lends itself towards implementing themes in environmental sustainability and community stewardship. I believe a global thinking approach encourages awareness in the general student population and brings real world relevance to the discipline. Sustainability themes (problems, examples, projects) offer an attractive template for all students to engage and think critically in complex and capacious issues (civic engagement and responsibility).

My commitment to this pedagogical approach is exemplified through serving as a SENCER Leadership Fellow (Science Education for New Civic Engagements and Responsibilities). The SENCER teaching philosophy is based on active engagement in matters of civic importance in the community and stimulates student involvement in a value based, multidisciplinary learning experience (SENCER 2011). Consistent with SENCER's goals, I deem my educator role at Ohio University Southern is to (a) get more students interested and engaged in learning in STEM courses, (b) help students connect STEM learning to their other studies, and (c) strengthen students' understanding of science and their capacity for responsible work, citizenship and their place in a greater environment.

Demographics

To be an effective educator also means that I must understand the local value system and learning modalities. Thus, I have been incorporating a storytelling format, particularly in our introductory biology courses, to reach our unique student body within its own historical framework (Carter, 2011). Most of our students reside in poverty-stricken Lawrence County, Ohio, and have limited access to travel outside of their communities. We represent one of the least educated regions in the nation. Located in the Appalachian Southeastern Ohio region, our students often have inadequate science backgrounds, are the first of their family to attend college, and are simultaneously juggling single parenting and full-time job responsibilities (Spohn, et al, 1992; Schwartz, 2004). Appalachian residents demonstrate lower academic achievement levels than the national average (Haaga, 2004). For example, in 2006 only 78 percent had graduated from high school, and while 30 percent matriculated at a college or university (compared to the national rate of 62 percent), only 7.9 percent eventually attained a baccalaureate degree (Harmon et al. 2003). County-level 2008 data from the U.S. Census Bureau revealed that 27 percent of children under 18 in the region were impoverished, compared with state and national averages of 18 percent. In this socioeconomic climate, residents of the region who do enroll in college are in danger of failure.

The Appalachian Rural Systemic Initiative (ARSI) ten-year study reports there exists an underlying ambivalence towards schooling in Appalachia and that, "Many of the few jobs in this region have centered on mining and more recently the penal industry, both of which only offer relatively low paying, hourly wages to workers. So for many Appalachians there is no strong immediate evidence that schooling and success in schooling leads to better economic opportunities or life style" (Inverness Research Associates, 2009). Furthermore, Haaga reports that a greater risk of college drop out is observed in distressed Appalachian counties, "partly through family environment (limited expectations for educational success), and when not counteracted by encouragement from teachers and other early mentors can be as great an impediment as the direct and opportunity costs of college attendance".

Engagement through Stories and Community

With fewer opportunities available for training scientists, my approach shifted towards developing active learning and regionally relevant studies. According to Dr. Greenley, Director of the Appalachian Ohio Scholars Program (personal communication), the regional population is steeped in a 'hands-on' culture that has traditionally shown little regard for theoretical models of learning. In the classroom, I elaborate on unfamiliar concepts through use of analogies among various biological systems and the human species (most interesting to students), e.g. highlighting common strategies in plant and human defenses. I take care to introduce, reinforce and then build upon the major concepts of the sub discipline throughout each term. The most difficult to conceptualize and complex ideas are delivered in a storytelling format with relevance to the region's history. This approach allows students to move beyond rote memorization and begin to truly comprehend the guiding principles of life sciences. The impact of this technique has been proven to successfully cross learning barriers fostered from years of cultural preconceptions and/or negative learning experiences (NRC, 1999; Mansouri, et al, 2009). My storytelling approach is often used as a springboard for addressing civic consequences, i.e. connecting the rich tradition of medicinal plants in Appalachian culture and the devastating effects of coal mining to environmental health.

It is always a good practice to stimulate student interest in the topic through involving them in their own instruction, e.g. breakout sessions to discuss thought provoking study questions. I attempt to explain challenging concepts concisely and in the most accessible way available, incorporating online discussion blogs, YouTube visualizations and textbook publisher-provided student tutoring sites. In a content-rich course, I look for cues that students have become "lost" in the course of explanation (especially in biology where ideas tend to build upon a growing foundation of knowledge). My non-traditional students are frequently more prepared for class and can be relied upon to share, not just their understanding of the subject matter, but also their experiences. Participation in this manner engages younger, less prepared students who are easily frustrated. Establishing open dialogue removes the isolating factor, as the 'smart ones' are more than happy to mentor their peers. This technique might not be effective in all learning environments, but rural students are still courteous to the viewpoints of elders in their community. Due to the controversial nature of teaching biological science in rural America, the value of this approach cannot be overstated.

Innoculating Agar Broth

Teaching Evolution in Rural America

The science community recognizes that success in the biological sciences is predicated on acceptance of its two major themes: the basis of evolutionary life and the cell theory (NABT, 2011). A negative outcome of rejecting either concept would logically present a limiting factor in student learning and progress in the sciences. In my experience with Appalachian rural students (even those choosing a career in the sciences), the topic of evolution has traditionally been met with considerable resistance. I attribute this attitude to the predominance of local faith-based community acceptance of Intelligent Design (Discovery Institute). A nearby, long-established Creation Museum (Petersburg, KY) accounting for the origin of the universe with humans and dinosaurs coexisting has never been demonstrably challenged within the hierarchy of a colloquial educational system (ARSI). Just ten years ago, a poll conducted by the Science Excellence for All Ohioans (SEAO, 2002) and Intelligent Design network sought support for design theory and origins science to be accepted by the Ohio Department of Education for 10th grade science students. According to SEAO, 'of the 309 pollsters, 84% respondents that are or have been engaged in biological sciences (n=98) favor objective origins science, and that 91% of those engaged in teaching or education are of the same mind.' Although SEAO's bid for modification of the science curriculum was not successful, sentiments against teaching natural selection in human evolution remains high. Biology professors in this rural setting understandably approach the teaching of evolution at the college level with a carefully stated, non-confrontational, 'I accept the scientific evidence for evolution'. In this context, teaching evolution is diverted away from waging belief system battles, which statements such as, 'I believe in evolution' might generate, and facilitates guiding our students to focus their scientific learning on testable hypothesis. There are still fractions of students that will shut their minds or angrily walk out when the subject is taught. However this approach averts the establishment of a community identity estranged from the expert in the classroom.

Students who have no interest in pursuing a science education may harbor multiple misconceptions about scientific principles and hot topics, such as climate change. Ideologies, which contradict accepted science-based positions, are reinforced through cultural/media articulations. Such ideologues are representative of learning modalities lacking individuality and critical analysis skills and which pose further challenges to educators in the sciences (Bashker and Frank, 2010). When I was asked to teach a human biology course for non-majors, I was initially stunned to discover that some students got angry when I told them men and women have the same number of ribs vs. the literal interpretation that Adam gave Eve a rib. Again I lost attendance, with the sound of an angry book closing, as I challenged preconceived beliefs. Realizing I was facing an upward battle to teach the scientific method to non-majors, I developed a new approach using a participation exercise. I inserted into my PowerPoint presentation a photo that I remembered taking during the medieval revelry-themed County Fair located in the western United States. The image was of a costumed couple, walking on stilts and angled in such a manner that they appeared twice as tall and wide as the crowds in the 'Sherwood Forest' trees. I referred to the couple as giant people (not one student challenged this). As I introduce the subject matter (scientific method), the 'giants' are dissected through a simple inductive reasoning and hypothesis testing. We can easily agree on the camera angle being misleading and infer new observations through inductive reasoning. The earlier (and false) interpretation given, based on a single observation and my authoritative opinion alone, is happily proven false. The class was then asked to collect their own 'giant people' stories from media sources to present to the class as an activity 'WWYB-What would you believe?' This fun exercise serves a dual purpose: to help students relax and become familiar with classmates in small teams and to question knowledge sources. The class is asked to assess whether each news report presented is believable, i.e. sightings of pink dolphins (true) or bats being blind (false). This exercise is a simple but effective early step toward inquisition and challenging conventional knowledge.

Applying SENCER Approaches

For science majors and non-majors alike, most students naturally realize the scientific process in the laboratory setting (NRC 2010, Popichak, 2008). Laboratory courses provide students with an excellent opportunity for multi-faceted and engaging learning experiences. Thus, I redesigned and expanded our laboratory experiments with visual aids and new laboratory equipment through NSF funding awarded to improve the learning experience in this underrepresented population. My laboratory format integrates problem-based and hands-on experiments designed to provide (a) introduction of the strategy to be employed with appropriate theoretical framing, (b) participant practice in the strategy in small groups and (c) whole group debriefing of the strategy and its use in the groups. Experiments in teaching are not necessarily successful. My criteria for success in the laboratory focuses on a demonstration that learning teams have synthesized information, have applied critical higher order thinking and were able to conceptualize what could have been done differently. Turning student frustration into great teaching moments is often possible, while obligatory rigor in applying the scientific approach helps them acquire a greater appreciation for how biological questions are answered.

To produce the science experience on our small campus, I have generated numerous undergraduate research projects and have several IRB and IACUC approvals on record to perform student research. These projects are always SENCER based, providing meaningful activities that address environmental issues in the region, i.e. collecting amphibians to test herbicide affects on reproductive development and studying micropropagation of an endangered medicinal plant. Developing sound ideas and feasible experimental methods through hypotheses testing and specific learning goals is vital to the success of student driven projects. My undergraduate researchers are exposed to this challenging approach to learning science. Currently, our campus has increased from just a handful of STEM students every few years to a significant improvement in science education that includes preparing posters and oral presentations, participating in plenary sessions at scientific meetings and performing SENCER orientated field and laboratory studies. By word of mouth around campus, students have begun dropping by my office seeking projects to increase their graduate school preparation. It's just a handful so far.

Lab Instruction

Student Impact

The personal impact of my job has been a renewed sense of purpose and satisfaction. I truly enjoy awakening the investigators within my students, and find pleasure observing an emerging inner confidence whenever a student begins to question and challenge the environment in which we live. One of my undergraduate researchers, a senior science education major, shared with me that taking my zoology class was the first opportunity he had been given to look under a microscope! Had he not chosen the path to take the more difficult majors level biology that I teach, and instead followed state minimum requirements (a couple non-majors biology course), he would never have experienced working in a laboratory, collecting scientific data or applying the scientific method. This senior later found himself the envy of his education classmates upon reciting his experiences in the field performing real research.

My hope is that the ideas and concepts I have exposed students to will have a lasting impact even once their formative years of study have passed, and regardless of whether continuing in a STEM discipline or contributing to their community in another manner. In closing, no discourse on effective teaching would be complete without commenting on the essential reality that we educators must care enough about the weight of our influence to refrain from treating students as children to please or entertain. Rather, it is imperative that we treat those we educate as responsible adults, and earn their respect and trust through caring enough to give them challenges. In this harder won approach, I believe, we best succeed to effectively foster and guide their intellectual growth.

About the Author

Orianna Carter (cartero@ohio.edu) received her bachelor's degree in biology from Keene State College and her doctoral degree in plant biochemistry and molecular sciences from Washington State University. Her published research has focused on studying the effects of natural products in human disease and the toxic effects of chemicals in the environment using cell culture and animal models. Carter teaches biology and pre-professional students at Ohio University and has been developing new general science education courses which incorporate engaging research experiences on sustainability with civic components.

References

Bashker, R. and Frank, C. 2010. "Interdisciplinarity and Climate Change: Transforming Knowledge and Practice for Our Global Futures." Bhaskar, R., Frank, C., Hoyer, K.G., Parker, J., ed. Ontological Explorations, New York, NY: Routledge Publ., 1-26 and 100-116.

Bransford, J., Brown A., and Cocking, R. 1999. "How People Learn: Brain, Mind, Experience, and School." National Research Council, Washington, DC: National Academy Press.

Calvert, J. and Harris, W. 2001. "Teaching Origins Science in Public Schools: Memorandum and Opinion, (accessed at: IDnet@att.net, Oct. 30, 2011).

Carter, O. 2011. "Fueling a Future Beyond the Coal Mines." Council for Undergraduate Research Quarterly, Highlights Focus Article, Spring, 31:23-28.

Discovery Institute http://www.intelligentdesign.org/resources.php, (accessed 11/13/11).

Haaga, J. 2004. "Educational Attainment in Appalachia." In Demographic and Socioeconomic Change in Appalachia, Washington, DC: Population Reference Bureau.

Harmon, H., Henderson, S., Royster, W. 2003. "A Research Agenda for Improving Science and Mathematics Education in Rural Schools." J. Research in Rural Education, 18:52-58.

Inverness Research Associates. 2009. Investing in the improvement of mathematics and science education in rural Appalachia: Ten Years of Arsi and its Accomplishments. http://www.inverness-research.org/arsi/a16arsi10yrinvest.html. (accessed November 21, 2011).

Mansouri, F., Jenkins, L., Leach, M., Walsh. M., 2009. "Building Bridges: Creating a Culture of Diversity." Institute for Citizenship and Globalization, 35-48, Carlton, Victoria: Melbourne University Press Publ.

National Association of Biology Teachers (NABT), Evolutionary Teaching: http://www.nabt.org/websites/institution/index.php?p=110 (accessed 12/5/11).

National Research Council. 2003. "BIO2010: Transforming Undergraduate Education for Future Research Biologists." Washington, DC: The National Academies Press.

Popichak, A. 2008. "Enhancing High School Science through Sensor-based Lab Exercises." In Innovative techniques in instruction technology, e-Learning, e-Assessment and education, J. Victor and M. Iskander, eds, Boston, MA: Kluwer Academic Publishing Group, 53-58.

Schwartz, J. 2004. Development and Progress of the Appalachian Higher Education Network. Washington, DC: Appalachian Regional Commission Executive Summary.

SENCER: Science Education for New Civic Engagements and Responsibilities. 2009. http://www.sencer.net, (accessed September 09, 20011).

Spohn, K. et al. 1992. Appalachian Access and Success: A Research Project of the Ohio Board of Regents and a Consortium of Two- and Four-Year Colleges and Campuses in Appalachian Ohio. Institute for Local government Administration and Rural Development. Columbus, OH.

Laboratories in a Democracy: Science and Hard Public Policy

Joseph J. Karlesky
Department of Government, Franklin & Marshall College

Abstract

Attaining the SENCER ideals of teaching basic science through public issues that are "complex, contested, and unresolved" and identifying the limits of science in helping us "decide what to do" can be facilitated by appreciation and analysis of the political pressures within the policy making process itself. Science and government depend on each other, but scientific facts and evidence do not have an inevitably sure path into the policy process. Strongly held and conflicting human values are reflected in contesting political interests that can have the power to shape the reception for scientific facts and evidence in the policy process. Outright rejection of facts, disputes over science-policy boundaries, and alternative framing of issues all help to explain the uncertainty that frequently awaits science in the policy process. The highest attainment of SENCER ideals lies in understanding both science and policy making as shapers of the future.

Introduction

Scientists in the trenches of their work know that doing inventive and worthwhile research taxes mind, body, and spirit. Supporting funds always seem to be scarce, false starts are distressingly common, pressure to publish can be unrelenting, experiments can resist sure replication, colleagues may be uncooperative, and flashes of understanding can be frustratingly elusive. Despite the frustrations, however, hard work and persistence, brilliant insight, and sometimes a bit of serendipitous luck can produce findings that literally change the world. But why is it so hard for government to produce related public policy, particularly when the findings of science have so much to offer? Why is debate over climate change, nuclear waste disposal, evolution, vaccination, embryonic stem cell research, and environmental strategies so durable? Why do governments have such difficulty deciding on public questions, especially when answers informed by science seem so obvious to so many?

These questions lurk in the core of the statement of SENCER ideals. Why are public issues that we use to reach and teach basic science "complex, contested, and unresolved?" Why does the enormous power of science that helps us to understand have such limits in helping us as a polity decide what to do? And why is the SENCER alert to "multidisciplinary trouble" so liberating as we try to engage students in our individual disciplines? Getting students to appreciate the rigors and wonders of basic science through the prism of public issues may have the ironic and welcome consequence of getting them to appreciate the rigors and wonders of public policy as well.

A Durable Interdependence

The relationship between science and government has a venerable history going back to the nation's founding. Among the powers the framers at the Philadelphia Convention of 1787 granted to Congress in the Constitution was the power "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." During the nineteenth century Congress created the Smithsonian Institution, land-grant colleges (now universities), the National Academy of Sciences, and the U.S. Geological Survey, all institutions that to this day continue to make scientific contributions to the nation. World war, the space race, and political demands for better health intensified this relationship between science and public policy in the twentieth century, as the Manhattan Project, NASA, civilian nuclear power, and a growing budget for the National Institutes of Health attest.

Science and government clearly need each other because neither can do its work without the contributions of the other. Researchers depend on government as the principal source of the funds that scientific investigation requires. As one example of this dependence, preliminary data indicate that the federal government in 2008 was the source of almost sixty-one percent of all funding for basic research done in universities and colleges, about three times more than the institutions themselves provided for basic research (U.S. NSF, 2010). The scope of such federal support for academic research is acknowledgement that without the contributions of science government literally cannot accomplish its missions, including developing advanced weaponry, exploring new energy sources, and finding cures for disease. Harvey Brooks neatly captured this close interrelationship between science and public policy by his classic conceptual formulation of "policy *for* science" and "science *in* policy" (1964, 76, emphasis added).

A timeless expression of the relationship between science and government at its best is the contribution of truth to power. In this model vision, knowledge guides power and is vitalized by it while simultaneously avoiding the potential impotence of science and potential mindlessness in public policy. Without political power to apply research results in public policy, truth in the form of scientific findings risks the impotence of having little impact in the larger society. At the same time, public decision making without the truth of scientific findings risks mindlessness in policy with potentially dire consequences for the larger society.

As the work of scientists and policy makers seeps into the work of the other, attempts to assess appropriate and mutually beneficial relationships between the two have long engaged science policy scholars. In a book chapter aptly titled "The Spectrum from Truth to Power," Don K. Price defines four sets of institutions or "estates" that must relate to each other in the making of public decisions: the scientific, the professional, the administrative, and the political. According to Price, the scientific end of the spectrum pursues "knowledge and truth" and the political deals with "power and action" (1965, 135). Each of the estates contributes to and respects the work of the others. But Price asserts that while scientists are "deeply involved in the major issues that confront a modern government…it is not easy to define the ways in which scientists should be given support by government and permitted to exercise their initiative or influence in policy issues of interest to government" (275). Alvin Weinberg posits the concept of "trans-science" to capture policy questions that are informed by science but cannot be definitively answered by it, necessitating broader public participation in ultimate decisions (1972a). For example, as nuclear scientists cannot guarantee the absolute safety of nuclear reactors and the disposal of radioactive waste, the broader society, with as much information as science can provide, must decide final policy questions on nuclear power and the risks it carries (1972b, 34).

Roger A. Pielke, Jr. focuses on scientists themselves and the various roles they can choose to play in the policy process. Pielke identifies these roles as pure scientist, science arbiter, issue advocate, and honest broker of policy alternatives (2007, 1-7). This spectrum of roles opens to scientists different paths to pursue, from explaining research findings themselves (pure) to answering questions about policy alternatives (arbiter) to pressing for a particular policy (advocate) to exploration of alternatives to broaden and enlighten the choices policymakers confront (broker). Pielke sees dangers to scientists who advocate particular policy positions because such advocacy threatens what he sees as the fruitful role for scientists in assuming the role of honest broker (135). Rather than similarly positing particular roles to scientists, Ann Campbell Keller in her analysis of science in environmental policy argues that the capacity of scientists to shape policy outcomes becomes more constricted as the policy process moves from the setting of agendas to the more formalized stages of legislating and implementing policy by executive agencies (2009, 13-14, 170). As the stakes in the policy process rise and final decisions come closer, scientists increasingly encounter the sharp edges of competing interests that rigorously press for their own policy ends.

Science has demonstrably produced enormous public goods, even though the relationship between scientists and policy makers has been troubled by conflicts both over which science fields should receive tax money support and the public uses to which the fruits of science should be applied. But the conflicts between science and public officials have perhaps never been greater than they have been at the beginning of the present century. Exploring why politics and science can be a combustive mixture and why the political world may be so resistant to findings of scientists can help to explain why so many public issues are contested, complex, and unresolved, an exploration that is in the true spirit of the SENCER enterprise.

Empiricism and Political Power

Scientists and public officials as discrete groups engage in fundamentally different kinds of work, with each profession having different goals, different skills and talents, different sets of pressures, and different standards of success than the other. The goal of science is "understanding nature" (Kranzberg 1968, 21), a purpose that researchers pursue through empirical investigation of the world about us. Scientists collect data, discern what is fact and what is not, mount experiments to test relationships, and develop theories to explain how facts fit together and how and why the part of the world they are studying actually works as it does. Scientists observe and, guided by evidence and theoretical constructs, explain. Their success is gauged by the replicability of their experimental findings and the fit of the facts to their theoretical explanations, as determined by rigorous review by their peers and publication of results for wide dissemination. In a seminal interpretation in the history of science, Thomas Kuhn instructs us that this process is subject to conflict and perturbation as new paradigms replace the old (1962, 156-158). But at the core of their work, scientists see themselves as guided by the search for understanding, no matter where the search leads. A powerful ingredient in the potentially combustive brew of science and politics is that this search sometimes risks leading to places where some people do not want to go.

While science seeks to understand, the ultimate goal of government and the political process is the making of public policies, highly diverse in ends such as protecting individuals from each other, exploring the solar system, preventing epidemics and finding cures for disease, running massive educational systems, increasing agricultural yields, and anticipating and coping with disasters resulting either from natural forces or human agency. As statutes, taxes, and regulations exemplify, government is the only institution in society that can make rules applying to everyone or requiring behaviors of particular classes of people or organizations.

The very gravity of this responsibility means that whatever government does or plans to do is ordinarily subject to intense scrutiny accompanied by either strong support or powerful opposition, depending on the interests of those affected by the government action. What do people or groups want, that is, what are their *interests*? For example, do they want a tax on fossil fuels to limit carbon emissions and global warming, or do they oppose such a tax because of its threat to the fossil fuel industry? In addition, do contesting groups have the capacity or political strength to get what they want? That is, do they have the *political power* to get Congress and the president to approve a fossil fuel tax as law or, alternatively, do their opponents have the political power to get Congress and the president to reject a fossil fuel tax? These questions about interests and the political power to advance interests lie at the heart of political conflict and the success or failure of individuals and groups in that conflict.

Conflict in the Making of Public Policy

Clashing judgments of what government should or should not do are a distinguishing characteristic of the policy process. At the time of the nation's founding more than two centuries ago and in a call to accept the new constitution the framers proposed, James Madison in *Federalist* No. 10 addressed an essential truth in human experience that the operation of government cannot escape:

> The latent causes of faction are thus sown in the nature of man; and we see them everywhere brought into different degrees of activity, according to different circumstances of civil society. A zeal for different opinions concerning religion,

> concerning government, and many other points, as well of speculation as of practice….So strong is this propensity of mankind to fall into mutual animosities that where no substantial occasion presents itself the most frivolous and fanciful distinctions have been sufficient to kindle their unfriendly passions and excite their most violent conflicts. But the most common and durable source of factions has been the various and unequal distribution of property…. (Shapiro 2009, 48-49).

The passage of centuries has changed the policy questions but not the fact of conflict itself.

As great literature and multidisciplinary attempts to plumb the human psyche demonstrate, no single explanation can capture why people disagree with each other in politics or any other realm of experience. According to political scientists, we get our perceptions of politics through a process of political socialization in which parents and families, teachers and schools, and peers are among the powerful shapers of our views of politics and policy. These shaping influences will differ in strength and direction from one individual to the next. In a provocative and intriguing analysis, some political scholars argue that political attitudes may have a genetic basis that compels consideration of the inheritability of genes interacting with environmental influences to shape political orientations (Alford, et.al. 2005). Demographic characteristics like education and income level, occupation, race, age, gender, and religious commitment lead to different life experiences that produce conflicting judgments on what government ought to do. These political differences can be like quicksand for scientific findings making their way into the policy process. The laboratory is tranquil compared to the cacophony of voices synonymous with the political struggle to get government to do some things but not others.

In debates that have racked the nation over the last decade and more, the fact of political conflict has enormous implications for science in public policy in substantive areas as diverse as biotechnology, public school curricula, climate change, and environmental strategies. Life scientists have high hopes for the therapeutic potential of research on stem cells derived from human embryos (IOM 2002, 34-36). But religious convictions that human embryos are lives deserving of protection (On Embryonic Stem Cell Research 2008) have embroiled federal funding of such research in controversy. Religious fundamentalists have refused to accept evolution (NAS/IOM 2008, 37-39), the organizing principle that explains changing life on the planet, because it violates their belief in the inerrancy of the Biblical account of creation. This rejection of evolution as an explanation has produced fights over how public school curricula should address pedagogy in biology (Kitzmiller 2005).

Among other powerful contestants of scientific findings in the shaping of public policy are economic self-interest and occupation. Research results that a chemical may be carcinogenic, or that a medical device may harm more than help, or that fossil fuels may change climate are all economically menacing to industries relying on such products. Creating a memorable quotation with very contemporary resonance, Upton Sinclair wrote "It is difficult to get a man to understand something, when his salary depends upon his not understanding it!" (1994, 109). The conflict between economic interests and scientific findings is nowhere more evident than in the political battle over strategies to cope with climate change. What seems obvious to the vast majority of climate scientists is threatening to the fossil fuel industry. The scientific consensus among climate researchers is that the earth is warming, in particular because of an increase in carbon emissions from the use of fossil fuel (NRC 2010, 27-28). However, the fossil fuel industry has vehemently argued in opposition that legislative efforts to limit carbon emissions will incur unacceptably high costs to consumers and the industry (API 2009).

In the high stakes of making public policies, government is essentially attempting to shape what the future will look like on a given issue. That different individuals and groups have alternative visions of what they think the future should look like lends public policy making its fascination, frustration, and importance. As individuals and groups contest with each other, government must make choices among alternative futures. Should we embark on a manned mission to Mars, or not? Should we levy taxes on carbon use to limit global climate change, or not? Should we use federal funds to support embryonic stem cell research, or not? Should we bury spent nuclear fuel in Yucca Mountain, Nevada, or not? Should we limit Environmental Protection Agency regulation of wetlands, or not? Government has the unique power to determine public policy by making such choices, with inevitably differential consequences for different individuals and groups. In Aaron Wildavsky's phrase, *policy politics* engages the question, "which policy will be adopted?" (1966, 304).

Government power to select from among alternative futures and make specific policy choices naturally invites unrelenting efforts by individuals and groups within and outside of government to shape government's ultimate decisions to their self-interests. Efforts to get government to choose specific policy futures can take a variety of forms, including working toward electoral victories or defeats of specific candidates, making cash campaign contributions to political candidates taking favored policy positions, lobbying officials directly, or engaging in policy argument to persuade others of the rightness of a particular point of view through a variety of media avenues, including speeches, commercial advertisements, and claims of specific interest cloaked in the guise of analysis. The fact of government power to make binding decisions invites, if not demands, these intensive efforts to persuade. A key question is the role that science plays in what is the struggle of persuasion that political power attracts.

Science in Policy Argument: Rejection, Boundaries, and Framing

Science has demonstrated enormous power to create basic knowledge about how the world works and has, consequently, fundamentally shaped many public policies, from national security to public health to agriculture. But depending on the policy area at issue, the transfer of scientific findings to the consequence of public policy can be halting and circuitous or perhaps even overtly impeded. To the chagrin of those seeing knowledge as the great clarifier in policy disputes, evidence and facts do not openly speak for themselves or lead to inevitable outcomes, especially when evidence is uncertain or seems to threaten other interests. Where contending interests are vigilant and the stakes are high, science can confront a variety of neutralizing strategies that include outright denial of facts inconvenient to an opposing interest, disputes over the proper boundaries between science and politics, and alternative framing of issues, all courses of action that enrich understanding of why public issues can be complex, contested, and unresolved.

The policy debate over vaccination and autism illustrates the power of passionate beliefs to reject science when it conflicts with those convictions. A 1998 medical article linked the rising rates of autism to childhood vaccines, setting off a storm of controversy about vaccination policy. Other researchers have since repudiated the article's findings, but to no avail in quelling the controversy. In groups accepting the linkage despite the repudiating research, the proclaimed desire to protect children and a suspicion of medical elites have combined to reject scientific findings that unreservedly find no link between autism and vaccines (Specter 2009, 57-101). Rejection of scientific facts has also occurred at the highest levels of government. In 2004 the Union of Concerned Scientists issued a sharp critique of the administration of President George W. Bush for suppressing or distorting scientific evidence in the implementation of public policy in a variety of areas, including climate change and air quality, in the service of political purposes and ends favored by the administration (UCS 2004). Frontal attacks on the truth of scientific findings are the clearest example of the surprisingly inhospitable reception scientific facts can sometimes get in the policy process.

Another category of reception science may receive in the policy process is not outright rejection but dispute over where science ends and where policy begins. The lines of demarcation between the two are not sharply delineated, however, particularly when scientific uncertainty meets policy options riven with value conflicts (Jasanoff 1987, 196-97). Controversies springing from government regulation of environmental and carcinogenic substance risk exemplify these boundary disputes and the role contesting interests play in defining the boundary. Sheila Jasanoff clearly articulates the stakes in these conflicts:

> [W]hile no one doubts that science should be done by scientists and policy by policy-makers, the problem for each interest group is to draw the dividing line between science and policy *in ways that enlarge its own control over social decisions*. Competition among these groups leads to differing definitions of the point at which the autonomy of science ends and the role of decision-making begins. (1987, 199-200, emphasis added)

Jasanoff analyzes disagreements between regulating agencies and the affected industry over, for example, the relative importance that should be attached to positive and negative studies of carcinogenic substance risk in the construction of regulations. Emphasis on positive studies would more likely lead to regulations detrimental to the chemical industry, which predictably claimed that ambiguity of findings should not be the basis for policy (205-11). Illustrating the crucial role that political interests play in the struggle to define the line between science and politics, industry pressed "to remove risk assessment from the control of agency scientists and bureaucrats, whom industry regarded on the whole as captive to pro-regulatory interests" (210). Jasanoff's research finds that once consequential policy decisions are in play, just what constitutes actionable scientific findings becomes part of the political argument.

Finally, beyond outright rejection and boundary disputes, science making its way into policy must cope with how public issues affected by science are framed and how they are received by interested participants in the process. Though framing is defined in different ways by different disciplines, Shanto Iyengar argues that "In operational terms…researchers have converged on a relatively loose definition of framing as information that conveys different perspectives on an issue" (2010, 188). Linked to the process of persuasion, framing is the "way in which opinions about an issue can be altered by emphasizing or de-emphasizing particular facets of that issue" (Iyengar and McGrady 2007, 219). Scientists try to persuade their peers through the publication of data and the replicability of experiments. In the broader arena of the policy process, however, persuaders use policy argument to try to get their way, and framing of issues in the service of specific interests is an example of policy argument that buffets the movement of data and experimental results into the policy arena.

The multiple surfaces of public issues can reflect the light of facts and information in a variety of ways, sometimes directly and sometimes obliquely revealing the purposes of the framers who define issues to mirror their interests. Global warming can be framed as an environmental crisis demanding attention, or as a dangerous ruse that will end up devastating traditional industries and their jobs; embryonic stem cell research as work potentially leading to life-saving therapies, or as heartless killing of innocent embryonic life; civilian nuclear power as an environmentally friendly fuel free of carbon emissions, or as an environmentally dangerous producer of long-lived toxic waste; child vaccination policy as a bolster to community health, or as the bearer of illnesses like autism; government mandates requiring health insurance as a way to disperse health care costs more fairly, or as a threat to the fundamental freedom from government that should protect against such coercive mandates.

Framers of public issues clearly want to shape public attitudes for any of the motivations common to human behavior, from preserving or promoting economic self-interest, to protecting and disseminating strongly held religious beliefs, to advancing specific ideological views that either cloak or openly celebrate particular economic values or belief systems. But the process is complicated by the findings of cognitive scientists that human brains are not simply blank slates or empty vessels that are written on or filled by external persuaders (Mooney 2010). Rather, we as individuals have cognitive frameworks that filter and process the vast amounts of information we receive to make it comprehensible or palatable or safe for us. That we are not blank slates is a fact that complicates the movement of scientific facts from laboratories to public policy.

George Lakoff argues that the Enlightenment view that facts and evidence will inevitably convince us if we are simply open to them must be replaced by a more accurate and textured view of how we reason, "reason incorporating emotion, structured by frames and metaphors and images and symbols, with conscious thought shaped by the vast and invisible realm of neural circuitry not accessible to consciousness" (2008, 14). Matthew C. Nisbett and Chris Mooney write that individuals use "perceptual screens" made up of "value predispositions (such as political or religious beliefs)" as they assess and interpret the information they confront. This perceptual screening explains the sharp partisan differences between Democrats and Republicans on whether humans are primarily responsible for global warming, partisan differences that exist despite the nearly unanimous scientific judgment that human activity plays a crucial role in creating the condition of warming (2007, 56).

Dan M. Kahan and his colleagues make a similar argument that the distribution of scientific facts must be accompanied by awareness that "cultural cognition strongly motivates individuals—of all worldviews—to recognize such information as sound *in a selective pattern that reinforces cultural predispositions*" (2010, 30-31, emphasis added). Cultural values can include a defense of commerce and industry, or an acceptance of the need for government regulation, or a celebration of individualism, or, alternatively, equality, or support for civilian nuclear power. Depending on the predispositions of individuals, cultural values like these will shape individual receptivity to scientific information, in the form of acceptance, skepticism, or outright opposition. Kahan and his colleagues, for example, argue that individuals amenable to the value of support for commerce and industry are likely to reject information on global warming as threatening to their values if resulting policy risks more government regulation. But they are likely to be more receptive to the information if they see global warming as affirming a value they support, such as the need for expansion of carbon-free nuclear power (2010, 31). The facts of science become more powerful convincers if persuaders recognize and acknowledge the very human values at stake in the persuasion.

Sensitivity to such human values in the communications process is crucial for scientists who hope their research findings will shape public policy. Ensuring that laboratory work makes a difference in the larger society requires attention to the audience that scientists must reach (Nisbet 2010, 41). Scientific facts about medicine and health, for example, can touch people in a more direct way if they are accompanied by personal narratives that demonstrate the power of evidence for individuals. As an illustration, specific accounts of illnesses in others caused by children who are not vaccinated can accentuate the persuasive power of scientific evidence confirming the need for vaccination (Meisel and Karlawish 2011, 2022). A burgeoning literature on the process of communicating science argues that successful transfer of information beyond the laboratory must acknowledge the special characteristics of media channels and the values and needs that move potential recipients of the information (Kahlor and Stout 2010, Russell 2010).

Public Policy and SENCER Ideals

In the drive to discover, to understand, to make connections among apparently unrelated phenomena, the scientific enterprise has been among the noblest expressions of the human spirit. The results have been astounding creations of ingenuity, from genetic modification of plants to increase agricultural yields, to the identification of cellular development to cure disease, to peeling away the dense layers of structural complexity in the cosmos to advance our comprehension of the universe. But the demonstrations of ingenuity have brought problems as well, from the unfathomable destructiveness of weapons, to threats to strongly held beliefs, to disturbances to powerful economic interests. The drive of the human spirit in science brings with it consequences that are often disparate and sometimes disconcerting. Science takes us to new places that are inviting to some and uninviting to others, a fact that is central to the relationship between science and public policy.

If they do anything, the findings of science change what the future will look like, in medicine, in agriculture, in national security, in our perceptions of the problems we face. But politics and public policy, too, like science, are expressions of the human spirit. They, too, have as their ultimate purpose the definition and determination of what the future will look like in particular policy areas. Since both science and public policy each in its own way essentially shapes the future, the interaction between the two, depending on the science and the issue, can produce mutual cooperation or sharp conflict. Whenever science touches deeply held human values, like protection of livelihood, or religious belief, or ideological predisposition, or fundamental sense of self, the facts of science can face a rocky terrain in the policy making process. Among the implications of new knowledge is that its dissemination cannot escape the very human trial of deciding how to proceed in the face of disagreement.

Doing basic science is hard and taxing work, though the truths it establishes about the world around us are intellectual treasures and bulwarks of our survival. But science and scientists, even when the evidence they produce is unambiguous, cannot make our policy choices about the future for us. The policy process in a democracy is often messy, frustrating, and even petty, but it is through that process, imperfect as it is with sharp value conflicts and power inequalities, that we ultimately decide the kind of future we want. The SENCER ideal of teaching basic science through "complex, contested, capacious, current, and unresolved public issues" simultaneously captures both the pursuit of truth in science *and* immersion in the human struggle to shape the future through the policy process. As researchers and teachers, we cannot ask for more.

About the Author

Joseph J. Karlesky (joe.karlesky@fandm.edu) is The Honorable and Mrs. John C. Kunkel Professor of Government at Franklin & Marshall College. He received his Ph.D. in Public Law and Government from Columbia University. His teaching and research interests focus on public policy, particularly the interrelationships between public policy and science and technology and the consequences of these interrelationships for policies in energy and health. He is co-chair of the public health program and regularly teaches courses in American government, understanding public policy, public policy implementation, and a seminar on health policy.

References

Alford, J. R., C. L. Funk, and J. R. Hibbing. 2005. "Are Political Orientations Genetically Transmitted?" American Political Science Review 99 (May): 153-167.

American Petroleum Institute. 2009. "Climate bill would outsource U.S. refining, energy security: study." http://www.api.org/Newsroom/refining_sector.cfm (accessed September 6, 2011).

Brooks, H. 1964. "The Scientific Adviser." In Scientists and National Policy-Making, R. Gilpin and C. Wright, eds., 73-96. New York: Columbia University Press.

Iyengar, S.2010. "Framing Research: The Next Steps." In Winning with Words: The Origins & Impact of Political Framing, B. F. Schaffner and P. J. Sellers, eds. 185-191. New York: Routledge.

Iyengar, S. and J. McGrady. 2007. Media Politics: A Citizens Guide. New York: Norton.

Institute of Medicine. Committee on the Biological and Biomedical Applications of Stem Cell Research. 2002. Stem Cells and the Future of Regenerative Medicine. Washington, D.C.: National Academy Press.

Jasanoff, S. S. 1987. "Contested Boundaries in Policy-Relevant Science." *Social Studies of Science* 17 (May): 195-230.

Jasanoff, S. S. 1990. The Fifth Branch: Science Advisers as Policymakers. Cambridge: Harvard University Press.

Kahan, D. M., H. Jenkins-Smith, and D. Braman, "Cultural Cognition of Scientific Consensus" (February 7, 2010). Journal of Risk Research, Vol. 14, pp. 147-74, 2011; Yale Law School, Public Law Working Paper No. 205. Available at SSRN: http://ssrn.com/abstract=1549444

Kahlor, L. and P. Stout, eds. 2010. Communicating Science: New Agendas in Communication. New York: Routledge.

Keller, A. C. 2009. Science in Environmental Policy: The Politics of Objective Advice. Cambridge: MIT Press.

Kitzmiller v. Dover Area School District, 400 F. Supp. 2d. United States District Court for the Middle District of Pennsylvania (2005).

Kranzberg, M. 1968. "The Disunity of Science-Technology." American Scientist 56 (Spring): 21-34.

Kuhn, T. 1962. The Structure of Scientific Revolutions. Chicago: University of Chicago Press.

Lakoff, G. 2008. The Political Mind: Why You Can't Understand 21st-Century Politics with an 18th-Century Brain. New York: Viking.

Meisel, Z. F. and J. Karlawish. 2011. "Narrative vs Evidence-Based Medicine—And, Not Or." Journal of the American Medical Association 306 (9 November): 2022-2023.

M ooney, C. "The Science of Why We Don't Believe Science." 2011. Mother Jones (May-June), http://motherjones.com/politics/2011/03/denial-science-chris-mooney (accessed September 13, 2011).

National Academy of Science and Institute of Medicine. 2008. Science, Evolution, and Creationism. Washington, D. C.: National Academies Press.

National Research Council, Board on Atmospheric Sciences and Climate. 2010. Advancing the Science of Climate Change. Washington, D.C.: National Academies Press.

Nisbet, M. C. and C. Mooney. 2007. "Framing Science." Science 316 (6 April): 56.

Nisbet, M. C. "Framing Science: A New Paradigm in Public Engagement." In Communicating Science: New Agendas in Communications, L Kahlor and P. Stout, eds. 40-67. New York: Routledge.

On Embryonic Stem Cell Research: A Statement of the United States Conference of Catholic Bishops. 2008. Washington, D.C.: United States Conference of Catholic Bishops.

Pielke, R. A., Jr. 2007. The Honest Broker: Making Sense of Science in Policy and Politics. Cambridge: Cambridge University Press.

Price, D. K. 1965. The Scientific Estate. Cambridge: Harvard University Press.

Russell, N. 2010. Communicating Science: Professional, Popular, Literary. New York: Cambridge University Press.

Shapiro, I., ed. 2009. The Federalist Papers, Alexander Hamilton, James Madison, John Jay. New Haven: Yale University Press

Sinclair, U. 1994. I, Candidate for Governor: And How I Got Licked. Berkeley: University of California Press.

Specter, M. 2009. Denialism: How Irrational Thinking Hinders Scientific Progress, Harms the Planet, and Threatens Our Lives. New York: Penguin Press.

Union of Concerned Scientists. 2004. Scientific Integrity in Policymaking: An Investigation into the Bush Administration's Misuse of Science. Cambridge: Union of Concerned Scientists.

U.S. National Science Foundation, Division of Science Resources Statistics. 2010.National Patterns of R&D Resources: 2008 Data Update. NSF 10-314. Arlington, VA. Available at http://www.nsf.gov/statistics/nsf10314. TABLE 2. U.S. basic research expenditures, by performing sector and source of funds: 1953-2008 (accessed August 23, 2011).

Weinberg, A. M. 1972a. "Science and Trans-Science." Minerva 10 (2): 209-222.

Weinberg, A. M. 1972b. "Social Institutions and Nuclear Energy." Science 177 (July 7): 27-34.

Wildavsky, A. 1962. The Political Economy of Efficiency: Cost-Benefit Analysis, Systems Analysis, and Program Budgeting. Public Administration Review 26 (December): 292-304.

RESEARCH ARTICLE

Reshaping How Educators View Student STEM (Science, Technology, Engineering, and Mathematics) Learning:

Assessment of the SENCER Experience

Janice Ballou
Independent Consultant

Introduction

There are innumerable government-commissioned reports documenting the need for improved STEM (science, technology, engineering and mathematics) education. These are exemplified by *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (2007) and the *National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering and Mathematics Education System* (2007). In 2010 the National Science Board report *Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation's Human Capital* emphasized the urgency of the issue: "to ensure the long-term prosperity of our Nation, we must renew our collective commitment to excellence in education and the development of scientific talent."

Complementing the need for improved STEM education identified by government-commissioned reports is the range of reports and studies focused on undergraduate learning experiences carried out by educators. Overviews of issues related to undergraduate education include *How College Affects Students* (Pascarella and Terenzini 2005), a synthesis of what is currently known about how college impacts students, and *Academically Adrift: Limited Learning on College Campuses* (Arum and Roksa 2011) an assessment of undergraduate student learning. There are also those focused on collegiate STEM experiences such as *Scientific Teaching* (Handelsman et al. 2004), *Vision and Change in Undergraduate Biology Education: A Call to Action* (Brewer and Smith 2011), *Inside the Schooled Mind: Review of Applying Cognitive Science to Education-Thinking and Learning in Scientific and Other Complex Domains* (Stern 2009) and others that report on how to improve science learning from both the student and educator perspective.

Science Education for New Civic Engagements and Responsibilities (SENCER) has supported a community of faculty, students, academic leaders, and others to improve undergraduate STEM education using an approach that connects learning to critical civic questions. [1] A SENCER description

1 This material is based upon work supported by the National Science Foundation under Grant No. 0717407. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

notes that the courses and programs "…explicitly embrace pedagogical strategies that reflect the recent scholarship of cognitive scientists on how we actually learn. These strategies emphasize learning that is active, authentic, inquiry-based, and connected to research" (SENCER Viewbook 2009). To put it succinctly, SENCER's dictum is "applying the science of learning to the learning of science" (SENCER Viewbook 2009). Specific SENCER goals are targeted to student outcomes: (1) get more students interested and engaged in learning in STEM courses, (2) help students connect STEM learning to their other studies, and (3) strengthen students' understanding of science and their capacity for responsible work and citizenship. (About SENCER http://www.sencer.net/About/projectoverview.cfm)

A 2006 report, *Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project* (Weston, Seymour, and Thiry, 2006) describes a SENCER program evaluation that focused on students and the development and validation of the survey instrument for Student Assessment of Learning Gains (SALG). [2] In a summary of the SALG data from more than 10,000 students in 345 SENCER courses the authors found it significant that: (1) students gained most in the areas of science literacy, followed by general course skills; (2) women gained more than men and non-science majors gained more than science majors on many of the items and composite variables; (3) the patterns of gains were in line with efforts by SENCER to encourage awareness of the link between civic issues and scientific content. The 2006 evaluation also included a survey and interviews with faculty selected from 135 instructors teaching SENCER courses.

In 2010 the SENCER Impact Assessment Survey was designed to find out from all program participants whether or not SENCER was meeting its objectives. Rather than test specific hypothesis, the research goal was to describe participants' views of their SENCER experience and use this information for future planning. In April 2011 SENCER eNews published a descriptive overview of the survey results. [3]

Methods

Participants

The 1,685 SENCER program participants who attended at least one national or regional event between 2001 and 2010 were contacted by e-mail to participate in a web-administered survey. Of these, 346 were returned due to bad e-mail addresses and five were not eligible evaluators associated with SENCER. Among the 1,334 eligible, 602 (45%) responded. Comparisons between respondents and all participants are limited. The only available SENCER administrative data that can be directly compared to survey respondents is the number of events program participants attended. This comparison shows that those who responded are more likely than all participants to have experienced more than six SENCER events (11.9% to 2.0% respectively) and 3 to 6 events (33.5% to 8.0% respectively) and less likely to be those participating in 1 or 2 national or regional SENCER events (54.3% to 89% respectively).

Survey Instrument

The survey instrument for the SENCER Impact Assessment Survey was developed by Stephanie Knight, Professor of Educational Psychology and Teacher Education at Penn State University and SENCER Director of Evaluation and Assessment; Richard Duschl, Chair in Secondary Education at Penn State University; and the SENCER Assessment and Evaluation Advisory Team.[4] The questionnaire covered multiple topic areas related to SENCER objectives: (1) the value of specific SENCER programs and resources; (2) professional and personal career development; (3) pedagogical practices (4) image of students as science learners; (5) student achievement; and (6) institutional change. Questions to categorize respondents included institution type (two or four year; public or private), role on campus, and number of national and regional SENCER events attended. Open-ended items gave respondents opportunities for verbatim answers to expand on the Likert-type close-ended choices. [5] Respondents were given the option to respond anonymously or to give their names and personal contact information.

---

2 Information about the Student Assessment of Learning Gains (SALG) can be found at http://www.sencer.net/Assessment/independentevaluation.cfm

3 The overview can be found at http://serc.carleton.edu/sencer/newsletters/52534.html .

4 Members of the SENCER Assessment and Evaluation Advisory Team included William E. Bennett, Stephen Carroll, Matthew Fisher, Jeannette Haviland-Jones, and Terry McGuire.

5 The questionnaire is available by contacting the SENCER national office.

Data Collection

Data collection using a web-administered questionnaire was conducted between October 13, 2010 and November 30, 2010. The e-mail request said the purpose of the survey was "to garner information about SENCER's impact, influence, and effectiveness to help us plan for the future." Five e-mail reminders, approximately a week apart, were sent to encourage survey participation. As noted above, 602 (45%) responded to the survey.

Data Analysis Plan

The focus of the analysis is descriptive. Using the survey data we can learn about respondents' perceptions of SENCER objectives related to: (1) using active learning—the SENCER foundation for pedagogical practice; (2) viewing students as science learners; and (3) achieving 21st Century learning goals. The data for this analysis is based on answers to the Likert-style response choices. [6]

Each of these core objectives has components associated with the SENCER approach. A review of the frequency distributions for the components identifies the areas where SENCER participation is perceived to have had more or less influence and provides planning information for potential areas where future SENCER programming needs to focus.

Cross tabulations were used to analyze respondent sub-groups. These sub-group categories are the number of national or regional SENCER events attended and the respondent's role on campus. Comparing the data for those who attended different numbers of events answers the question of whether or not SENCER attendance has a cumulative effect on meeting SENCER objectives. The role on campus analysis compares answers of those who identify as faculty to responses from academic administrators, a group that includes a variety of positions such as program directors, department chairs, deans, provost, vice president, and chancellors. The faculty member viewpoint is expected to be primarily based on the application of his or her SENCER program experience in the classroom. Looking at the academic administrators' responses provides the perspective of institutional decision makers whose experience can be used to facilitate the institutional classroom adoption of the SENCER approach.

The open-ended questions related to these SENCER objectives described as being included in the survey instrument have not been analyzed. The development of a coding frame and a systematic process to categorize the text of the verbatim responses is a future research objective.

6 Individuals or teams interested in using the survey data for their own analysis should contact the SENCER national office.

Results

Profile of Survey Respondents.

Survey respondents were primarily faculty (66.7%) with about one-in-five reporting an administrative role on campus such as department chair (11.5%), dean (5.2%), and provost, vice president, president, or chancellor (2.5%). Fourteen percent had other roles on campus primarily in other administrative positions such as program directors. Most were from four-year (85.5%) compared to two-year (14.5%) institutions, and somewhat more were from public (55.2%) than private (44.8%) institutions. A majority of respondents participated in one or two national or regional SENCER events (54.3%), a third participated in three to six events (33.5%), and 1-in-10 experienced more than six SENCER events (11.9%). Examples of these "events" are the intensive SENCER Summer Institute, the three-day Washington, DC Symposium and Capitol Hill Poster Session, and various regional training programs and workshops. (Table 1)

TABLE 1. Profile of Survey Respondents

	PERCENTAGES	NUMBER
ROLE ON CAMPUS		
Faculty Member	66.7	349
Department Chair	11.5	60
Dean	5.2	27
Provost, Vice President, President, Chancellor	2.5	13
Other	14.1	74
INSTITUTE TYPE		
2 Year	14.5	76
4 year	85.5	447
INSTITUTE TYPE		
Public	55.2	285
Private	44.8	231
NUMBER OF SENCER EVENTS		
1-2	54.3	284
3-6	33.5	175
More than 6	11.9	62

Source: 2010 SENCER Impact Assessment Survey

Educators' Views of SENCER Influence on Student STEM Education

The SENCER Impact Assessment Survey had three questions related to SENCER objectives focused on students. These are the use of active learning—the SENCER foundation for pedagogical practice; perception of students as science learners; and student achievement of 21st Century learning goals.

Pedagogical practice

To learn whether or not SENCER participation influenced their pedagogical practice respondents were asked to strongly agree, agree, disagree, or strongly disagree if it increased student learning opportunities to: (1) identify scientific problems and questions; (2) conduct measurements and/or observations to develop data sets; (3) analyze data sets to determine evidence or the need to conduct more measurements and observations; (4) analyze evidence to determine patterns; (5) analyze evidence to construct models; (6) use evidence patterns and/or models to generate or evaluate explanations; (7) make connections between science and civic problems/topics; and (8) make interdisciplinary connections.

Overall, about 8-in-10 or more strongly agreed or agreed that SENCER participation influenced instruction that increased student opportunities to experience all eight of these components of pedagogical practice. (Table 2) When the eight are rank ordered, the highest percentages of agreement are for respondents' perceptions of increased student opportunities to make connections between science and civic problems/topics (95.2%), make interdisciplinary connections (94.7%), and identify scientific problems and questions (91.4%). The other five student learning opportunities are ranked as follows: analyze evidence to determine patterns (84.1%), conduct measurements and/or observations to develop data sets (84.0%), analyze evidence to construct models (83.6%), analyze data sets to determine evidence or the need to conduct more measurements and observations (80.9%), and use evidence patterns and/or models to generate or evaluate explanations (79.3%).

TABLE 2. SENCER Influence on Pedagogical Practices to Increase Student Opportunities (Strongly Agree/Agree Percentages)

		NUMBER OF SENCER EVENTS ATTENDED			ROLE ON CAMPUS	
PEDAGOGICAL PRACTICE	Total (n=485)	1-2 (n=256)	3-6 (n=168)	More than 6 (n=60)	Faculty (n=332)	Academic Administrator (n=135)
Make connections between science and civic problems/topics	95.2	91.7	98.7	100 ***	93.9	97.9
Make interdisciplinary connections	94.7	91.4	100	100 ***	93.1	98.0 *
Identify scientific problems and questions	91.4	88.9	93.6	96.1 ***	90.1	94.3 *
Analyze evidence to determine patterns	84.1	77.5	90.2	94.4 ***	82.3	88.5 *
Conduct measurements and/or observations to develop data sets	84.0	79.1	88.6	91.7 ***	81.4	90.3 *
Analyze evidence to construct models	83.6	78.0	87.9	94.3 **	87.7	76.3 *
Analyze data sets to determine evidence or the need to conduct more measurements and observations	80.9	74.7	87.0	89.8 ***	77.9	87.8 *
Use evidence patterns and/or models to generate or evaluate explanations	79.3	73.4	83.3	92.1**	80.8	89.9 *

Source: 2010 SENCER Impact Assessment Survey

Note: Due to item nonresponse, the number answering each of these items varied. The numbers on the table represent the maximum of the following ranges: Total 485-401; Number of SENCER events: 1-2 events 256-211; 3-6 events 168-138; more than 6 events 60-48; Role on Campus: Faculty 332-279; Not Faculty 153-122.

Pearson Chi -Square significance test
*P<.01
**P<.001
***P<.0001

Perceived SENCER influence by event attendance

The more SENCER events a respondent attended the more likely he or she was to strongly agree or agree that SENCER participation influenced pedagogical practice. A comparison of the three groups illustrates the extent of SENCER influence varies depending on the number of events attended.

Attended more than six events. All eight student learning opportunities were perceived to have had SENCER program influence by 9-in-10 or more of this attendee group. Of particular note, is unanimous agreement that SENCER had an influence on increasing student opportunities to make connections between science and civic problems/topics and to make interdisciplinary connections.

Attended three to six events. Four of the eight student learning opportunities received agreement from 9-in-10 of the respondents in this group. Making interdisciplinary connections stands out with unanimous strongly agree or agree responses.

Attended one or two events. Two of the eight student learning opportunities were perceived by 9-in-10 of these attendees as being influenced by SENCER participation. These are to: make connections between science and civic problems/topics (91.7 %) and make interdisciplinary connections (91.4 %).

Perceived SENCER influence by role on campus

Overall, about 8-in-10 or more faculty and academic administrators strongly agreed or agreed that SENCER participation influenced pedagogical practice to increase student opportunities for the eight components of this SENCER objective. Nine in ten academic administrators agreed with five of the eight components of student opportunities compared to three of the eight perceived to be influenced by 9-in-10 faculty. Academic administrators were more likely than faculty to report agreement to all these activities except increasing student opportunities to analyze evidence to construct models (76.3% to 87.7 % respectively).

These results are overwhelmingly positive and suggest that the SENCER program is perceived by respondents to be meeting its objective to influence pedagogical practice. Of particular note is the core SENCER objective to make connections between science and civic problems is perceived as influencing almost all respondents. The rank order of the eight components is instructive for identifying those that may need more attention in future SENCER programs. The data showing the perception of influence increases with the number of events attended illustrates SENCER's cumulative effect on attaining its objectives. SENCER influence on pedagogy is perceived similarly by faculty and academic administrators suggesting a consensus that can aid in moving the SENCER approach from individual classrooms to an institutional focus.

Image of students as science learners

A SENCER objective is to transform perceptions of students as science learners. Respondents were asked if they strongly agree, agree, disagree, or strongly disagree that involvement in SENCER influenced their image of students as science learners who are able to: (1) ask scientifically oriented questions; (2) use evidence to develop and evaluate explanations to address scientifically oriented questions; (3) formulate explanations from evidence to address scientifically oriented questions; (4) evaluate their explanations in light of alternative explanations; (5) respond to criticism from others; (6) formulate appropriate criticism of others; (7) seek criticism of their own explanations; (8) reflect on alternative explanations/phenomena that do not have unique resolutions; (9) translate the knowledge gained to other courses; and (10) take the knowledge gained and apply it in a civic/community setting.

For all ten components of this SENCER objective, 3-in-4 or more strongly agreed or agreed SENCER participation changed their perceptions of students' abilities as science learners (Table 3). The rank order of science abilities suggests where SENCER is having more or less influence. Eight-in-ten or more agreed SENCER changed their perceptions that students are able to: take the knowledge gained and apply it in a civic/community setting (92.2%); translate the knowledge gained to other courses (89.6%); use evidence to develop and evaluate explanations to address scientifically oriented questions (88.7%); ask scientifically oriented questions (88.1%); formulate explanations from evidence to address scientifically oriented questions (87.4%); reflect on alternative explanations/phenomena that do not have unique resolutions (86.9%); and evaluate their explanations in light of alternative explanations (86.3%). Fewer, agreed that SENCER influenced their image of students' abilities to: formulate appropriate criticism of

TABLE 3. SENCER Influence of Image of Students as Science Learners Able to do the Following (Strongly Agree/Agree Percentages)

		Number of SENCER Events Attended			ROLE ON CAMPUS	
STUDENT SKILL INFLUENCED	TOTAL (n=452)	1-2 (n=237)	3-6 (n=155)	More than 6 (n=59)	Faculty (n=310)	Academic Administrator (n=144)
Take knowledge gained and apply it in a civic/ community setting	92.2	88.6	96.1	96.6 **	90.9	95.1
Translate knowledge gained to other courses	89.6	84.1	96.1	94.6 ***	88.1	92.8
Use evidence to develop and evaluate explanations to address scientifically oriented questions	88.7	82.9	95.3	94.8 ***	87.1	92.2
Ask scientifically oriented questions	88.1	83.0	93.4	94.8 ***	86.3	91.7
Formulate explanations from evidence to address scientifically oriented questions	87.4	82.1	92.8	94.9 **	85.9	90.8
Reflect on alternative explanations/phenomena that do not have unique resolutions	86.9	81.7	91.7	94.8 **	85.9	89.0
Evaluate their explanations in light of alternative explanations	86.3	80.4	94.0	95.7 ***	84.7	89.4
Formulate appropriate criticism of others	77.2	71.4	81.7	87.5 *	75.8	79.9
Respond to criticism from others	76.5	71.1	80.2	87.2 *	74.1	81.5
Seek criticism of their own explanations	75.9	70.3	79.2	89.1 *	73.7	80.2

Source: 2010 SENCER Impact Assessment Survey
Note: Due to item nonresponse, the number answering each of these items varied. The numbers on the table represent the maximum of the following ranges: Total 452-410; Number of SENCER events: 1-2 events 237-213; 3-6 events 155-139; more than 6 events 59-55; Role on Campus: Faculty 310-274; Not Faculty 144-134.
Pearson Chi -Square significance test
*P<.01
**P<.001
***P<.0001

others (77.2%); respond to criticism from others (76.5%); and seek criticism of their own explanations (75.9%).

Perceived SENCER influence by event attendance

Similar to the data described for the pedagogical practice objective, the more SENCER events a respondent attended, the more likely he or she was to strongly agree or agree that participation had an influence on the image of students as science learners who are able to accomplish STEM related activities.

Attended more than six SENCER events. Among those who attended the most SENCER events, about 9-in-10 agreed that SENCER had influenced their image of students for all ten components of this SENCER objective. Take knowledge gained and apply it in a civic/community setting (96.6%) and evaluate their explanations in light of alternative explanations (95.7%) had the highest percentages of agreement. The student science abilities related to criticism were least likely to be perceived as influenced by SENCER involvement: seek criticism of their own explanations (89.1%); formulate appropriate criticism of others (87.5%); and respond to criticism from others (87.2%).

Attended three to six SENCER events. Seven of the ten abilities had agreed answers from 9-in-10 of the respondents in this group. Similar to the group who attended more than six events, the abilities related to criticism were least likely to be perceived as being influenced: formulate appropriate criticism of others (81.7%); respond to criticism from others (80.2%); and seek criticism of their own explanations (79.2%).

Attended one or two SENCER events. None of the ten components related to the image of students as science learners had agreement from 9-in-10 of those who attended the fewest number of events. However, 8-in-10 agreed with seven of the ten abilities. As with the other attendee groups, the lowest percentages of agreement were for the image of student's ability to: formulate appropriate criticism of others (71.4%); respond to criticism from others (71.1%); and seek criticism of their own explanations (70.3%)

Perceived SENCER influence by role on campus

For all ten components related to the SENCER objective of influencing the image of students as science learners, academic administrators were more likely than faculty to strongly agree or agree. Nine in ten academic administrators strongly agreed or agreed with five of the abilities compared to faculty who only had 9-in-10 agree with one. For both faculty and academic administrators the highest percentage of perceived influence was on the image of students being able to take the knowledge gained and apply it in a civic/community setting (90.9 % and 95.1% respectively). As with the attendee groups, the lowest percentages of agreement for faculty and administrators were for the image of student's ability to: formulate appropriate criticism of others (75.8% and 79.9 % respectively); respond to criticism from others (74.1% and 81.5 % respectively); and seek criticism of their own explanations (73.7% and 80.2% respectively)

As these robust results show, SENCER is perceived as meeting the objective of influencing participants' views of students as science learners. It is informative that among the ten components of this image of students, the abilities fewer perceive as being influenced are those related to criticism. Again the cumulative impact of SENCER attendance is observed with more SENCER experience being related to higher perceptions of influence for more of the components of this objective. And, those with faculty and administrative roles have similar perceptions on whether or not SENCER participation influenced their image of students as science learners.

Student achievement of 21st Century learning goals

Facilitating student achievement of 21st Century learning goals is another SENCER program objective. Respondents were asked if SENCER participation had helped student achievement a great deal, some, not much, or not at all with these components of 21st Century learning goals: (1) quantitative literacy; (2) ability to engage in critical thinking; (3) capacity to collaborate or engage in group work; (4) ability to discern good information from fraudulent claims; (5) cultivation of a global perspective; and (6) problem solving.

Overall 8-in-10 or more respondents answered that all six components of 21st Century learning goals had helped a great deal or some (Table 4). The top ranked 21st Century learning goals respondents perceived as being influenced by SENCER were: ability to engage in critical thinking (91.8%);

TABLE 4. Perceived SENCER Participation Help for Student Achievement of 21st Century Learning Goals (Great Deal/Some Percentages)

		NUMBER OF SENCER EVENTS ATTENDED			ROLE ON CAMPUS	
21ST CENTURY ACHIEVEMENT GOALS	TOTAL (n=463)	1-2 (n=239)	3-6 (n=166)	More than 6 (n=58)	Faculty (n=317)	Academic Administrator (n=146)
Ability to engage in critical thinking	91.8	86.5	96.4	100 ***	88.9	97.9 *
Capacity to collaborate or engage in group work	90.4	85.0	97.0	94.7 ***	88.9	95.2 *
Problem solving	88.7	83.2	93.9	96.5 ***	86.2	94.5 *
Cultivation of a global perspective	82.5	77.3	83.8	100 ***	79.1	89.9 *
Ability to discern good information from fraudulent claims	82.3	76.6	85.8	94.8 ***	79.3	89.0 *
Quantitative literacy	80.5	73.2	86.6	92.8 ***	79.0	83.9

Source: 2010 SENCER Impact Assessment Survey

Note: Due to item nonresponse, the number answering each of these items varied. The numbers on the table represent the maximum of the following ranges: Total 463-436; Number of SENCER events: 1-2 events 239-222; 3-6 events 166-156; more than 6 events 58-55; Role on Campus: Faculty 317-300; Not Faculty 146-136.

Pearson Chi -Square significance test

*P<.01

**P<.001

***P<.0001

capacity to collaborate or engage in group work (90.4%); and problem solving (88.7%). Somewhat fewer were influenced by SENCER programs a great deal or some to help students achieve: cultivation of a global perspective (82.5%); ability to discern good information from fraudulent claims (82.3%); and quantitative literacy (80.5%) (Table 4).

Perceived SENCER influence by attendance

Similar to the other two SENCER objectives, the more events a respondent attended, the more likely he or she was to answer this participation helped their students a great deal or some to achieve six 21st Century learning goals.

Attended more than six SENCER events. All six components of 21st Century learning goals for students were perceived by 9-in-10 of these attendees to have been helped a great deal or some by SENCER participation. Most noteworthy, is the unanimous view that their SENCER experience helped their students' ability to engage in critical thinking (100%) and cultivation of a global perspective (100%) a great deal or some.

Attended three to six SENCER events. Among these attendees, 9-in-10 answered a great deal or some for three of the 21st Century learning goals: students' capacity to collaborate or engage in group work (97.0%), ability to engage in critical thinking (96.4%), and problem solving (93.9%) received the highest percentage of a great deal or some answers.

Attended one or two SENCER **events.** None of these 21st Century learning goals had great deal or some answers that exceeded 90 percent from this group of attendees. Three components of this SENCER objective had 8-in-10 who perceived the SENCER experience helped students learn to: engage in critical thinking (86.5%), collaborate or engage in group work (85.0%), and solve problems (83.2%).

Perceived SENCER influence by role on campus

About 8-in-10 or more faculty members and academic administrators view SENCER participation as an aid to preparing students to achieve 21st Century learning goals. For all six components of this SENCER objective academic administrators were more likely than faculty to perceive students were helped a great deal or some because of SENCER participation. The components that rank highest for both academic administrators and faculty are ability to engage in critical thinking (97.9 % and 88.9% respectively) and capacity to collaborate or engage in group work (95.2% and 88.9% respectively).

Respondents clearly perceive that SENCER participation has helped students attain 21st Century learning goals. Again, SENCER planning can benefit from the descriptive rank order of the components to target possible revisions in this program objective. In addition, knowing that there is an increase in perceived SENCER influence related to event attendance is encouraging to overall incorporation of the SENCER approach to student STEM education.

SENCER events provide participants with learning theories and the methods to apply them. The survey results are testimony to how successful this approach is in practice and illustrate the extent of influence on student accomplishments.

Discussion

The urgency for improved undergraduate STEM education can not be overstated. The message that there is a need to transform how students learn and to broaden inclusion comes from government and academic leaders. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* was commissioned by Congress and challenges the status quo and points to necessary changes. Answering this challenge, the National Science Foundation Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) provides support "to transform undergraduate STEM education, for example, by bringing about widespread adoption of classroom practices that embody understanding of how students learn most effectively."

At the core of student learning is how they are taught. Studies such as *How People Learn: Bridging Research and Practice, Enhancing the Instructional Environment* and others illustrate how active learning as a pedagogical approach to teach science is gaining support. However, as suggested in *Scientific Teaching*, "reports generally do not offer a guide to learning how to do scientific teaching" and *Creating the Future of Faculty Development: Learning from the Past, Understanding the Present* provides suggestions for improving teaching. SENCER program participation is viewed as addressing this issue by influencing pedagogical skills such as using active learning for student experiences such as identifying problems, using scientific methods, and making connections to apply scientific knowledge to current social issues.

Other research to identify ways to improve STEM education looks at expectations for student learning. Scholars such as Rhona Weinstien, *Reaching Higher: The Power of Expectations in Schooling*, and others point to a more ecological/ holistic view of how students learn that is anchored in perceptions, expectations, and self- fulfilling prophecies in schooling. This field of pedagogy looks at the influence of learning expectations based on how teachers view students, teacher/student relationships, and the culture and environment where learning takes place. Applying this to STEM learning, the typical "perception" that non-science majors and women are least likely to "succeed" in science courses may become a self-fulfilling prophecy.

The SENCER objective to influence how educators view students addresses this approach to student learning. The survey results clearly indicate there is a perception that SENCER attendance influences participants' image of students as science learners. For this objective the SALG results summarized in a prior section indicate how changing educators' views can influence students as science learners. The SALG results show that among these students who were taught by SENCER program participants women gained more than men and non-science majors gained more than science majors on many of the items and composite variables. The SALG evaluators note this as "encouraging evidence given that females and non-science majors have traditionally been underserved or overlooked in many university science programs."

Transforming undergraduate STEM education is the core objective of the SENCER program. The SENCER Impact Assessment Survey was conducted to find out whether or not SENCER program attendance influences the various objectives related to this goal. As the robust descriptive results show, overall respondents perceive their pedagogical practice, perception of students as science learners, and ability to help students achieve 21st Century learning goals was influenced by attending SENCER programs. The description of the components of these objectives and the types of participants where there is more or less consensus on perceived SENCER influence can inform SENCER planning and contribute to addressing the challenges related to improving STEM education.

About the Author

Janice Ballou is a nationally recognized survey research methodologist with more than 40 years of experience. Currently an independent consultant, before retirement Ballou was a Vice President and Senior Fellow at Mathematica Policy Research, Inc. Her prior position was Director of the Rutgers University Center for Public Interest Polling. Her publications include "Survey Data Collection Methods" a chapter in *Counting Working-Age People with Disabilities: What Current Data Tell Us and Options for Improvement*, and "Web of Caring: Development of Web-Survey Best Practices" and "Diversity of Methods: Assessment of Quantitative and Qualitative Research Multiplier Effect" in *Proceedings of the American Statistical Association Section on Survey Research Methods*. She has held multiple American Association for Public Opinion Research elected offices and served on the *Public Opinion Quarterly* Advisory Committee and the *Survey Practice* Editorial Board.

Acknowledgements

The author would like to thank Danielle Kraus Tarka for the survey background information and contribution to the references and the reviewers for their helpful comments.

References

Arum, R. and J. Roksa. 2011. Academically Adrift: Limited Learning on College Campuses. Chicago: University of Chicago Press.

Bransford, J.D., Donovan, M.S., & Pellegrino, J.W. (1999). How People Learn: Bridging Research and Practice. Washington, DC: National Academy Press.

Brewer, C.A. & Smith, D. (Eds.). (2011). Vision and Change in Undergraduate Biology Education: A Call to Action. Washington, DC: American Association for the Advancement of Science.

Committee on Science, Engineering, and Public Policy. (2007). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, DC: The National Academies Press.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S.M., & Wood, W.B. (2004). "Scientific Teaching." Science, 304(5670), 521-522. Retrieved from www.sciencemag.org.

Lawrenz, F., Huffman, D. & Appeldoorn, K. (2005). "Enhancing the Instructional Environment: Optimal Learning in Introductory Science Classes." Journal of College Science Teaching, 34(7), 40-44. Retrieved from http://www.nsta.org/publications/browse_journals.aspx?journal=jcst&year=2005.

National Science Board. (2010) Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation's Human Capital. 2010. NSB 10-33 http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf.

National Science Board. (2007). National Action Plan for addressing the Critical Needs of the U.S. Science, Technology, Engineering and Mathematics Education System. Arlington, VA: National Science Foundation. Retrieved from http://www.nsf.gov/nsb/documents/2007/stem_action.pdf.

National Science Foundation (2010). Program solicitation for the Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES), http://www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5741&ods_key=nsf10544.

Pascarella, E.T. and P.T. Terenzini. (2005). How College Affects Students: A Third Decade of Research. 3rd ed. San Francisco: Jossey-Bass.

National Center for Science and Civic Engagement. (2007). SENCER Viewbook.

Sorcinelli,M.D., Austin, A.E., Eddy,P. , & Beach,A.L. (2005) Creating the Future of Faculty Development: Learning from the Past, Understanding the Present. Bolton, MA: Anker Publishing Company, Inc.

Student Assessment of their Learning Gains, http://salgsite.org/.

Stern, E. (2009). Inside the schooled mind: Review of Applying cognitive science to education – thinking and learning in scientific and other complex domains. Science, 323(5910), 40. Retrieved from www.sciencemag.org.

Weinstein, R.S. (2002). Reaching Higher: The Power of Expectations in Schooling. Cambridge, MA: Harvard University Press.

PROJECT REPORT

Development of the *Environmental Forum*: An Integrative Approach

Michael Berger
Simmons College

Jack Duggan
Wentworth Institute of Technology

Ellen E. Faszewski
Wheelock College

Abstract

With the assistance of SENCER, Colleges of the Fenway (COF) faculty developed a unique course in 2005 titled *Environmental Forum*. The *Forum* provides a common ground for students at all COF institutions to learn about current issues in sustainability and environmental topics and interact with other COF students and faculty. This course promotes networking opportunities and service learning throughout the Boston community in various areas related to sustainability and the environment. Over the past six years, the *Forum* has addressed broadly engaging topics with a sharpened focus, increased both the extent and formality of student community engagement, and expanded the assessment toolbox. Students highly rated the *Forum* for its variety of invited expert speakers, the opportunity to engage in discussion and debate, the ability to become aware of a variety of career options, and the ability to participate in service-learning and community engagement projects.

Introduction

In 2003, with the help of the Science Education for New Civic Engagements and Responsibilities (SENCER) dissemination project, faculty members from the Colleges of the Fenway (COF) consortium created a cornerstone course as part of a newly developed Bachelor of Science Degree in Environmental Science. *Environmental Forum,* created to provide a common identity for all environmental science students at the COF institutions, brings together students, faculty and practicing professionals to discuss current issues, career planning, and civic engagement as well as to participate in service learning activities throughout the COF and greater Boston communities. An initial assessment of student learning outcomes was previously reported (Faszewski and Duggan, 2007). Since then, due to changing student interest, the COF initiative has transformed into the COF Center for Sustainability and the Environment, and, as a result, *Environmental Forum* has adapted to reflect these changes. Recognizing the broader audience participating in the Forum, faculty has used a more interdisciplinary and integrative approach with respect to community engagement, service-learning, and assessment. Table 1 is an overview of development of the *Forum*.

TABLE 1. Development of the *Environmental Forum*

	2005	2006	2007	2008	2009	2010	2011
Community Engagement	Environmental NGOs	Environmental NGOs	Environmental NGOs	Environmental NGOs	Environmental NGOs	Environmental NGOs	Environmental NGOs
	Earth Day Cleanup	Earth Day Cleanup	Earth Day Cleanup	Earth Day Cleanup	Earth Day Cleanup	Earth Day Cleanup	Earth Day Cleanup
			Muddy River Symposium	Muddy River Symposium	Muddy River Symposium	Muddy River Symposium	Muddy River Symposium
Theme	Current Issues	Current Issues	Muddy River	Climate Change	Climate Change	Climate Change	Climate Change
					Sustainability	Sustainability	Sustainability
						Environmental Health	Sustainable Energy
Assessment Tools	Reflections	Reflections	Reflections	Reflections	Reflections	Reflections	Reflections
	SALG	SALG	SALG	SALG	SALG	SALG	SALG
					Pre and Post Self Assessments	Pre and Post Self Assessments	Pre and Post Self Assessments
					Content Assessments	Content Assesssments	Content Assesssments
						Scott Ross Center Involvement	Scott Ross Center Involvement

Environmental Forum Content Themes

The *Environmental Forum* course was initially designed to provide an arena for multi-disciplinary investigation into current environmental topics. The course originally focused on a wide array of general environmental issues, covering five to ten topics per semester. In 2007, however, faculty decided that instead of covering a number of unrelated environmental topics dictated by the availability of expert speakers to present at the Forum, it would be more beneficial to focus on a specific thematic issue in greater depth. With this in mind, each of the following topics was covered, one per semester: Muddy River Restoration Project, Climate Change, Sustainability, Environmental Health, and Sustainable Energy.

A number of advantages of increasing a thematic focus were readily apparent: clarity in the marketing of the *Forum* course (easier for students to understand what the course would consist of if the title included the main topic, e.g., Environmental Health), a greater depth of content was achieved through the incorporation of readings and texts, etc. In addition, during this time, an administrative transition in the consortium from an Environmental Science Program to a Center for Sustainability and the Environment resulted in a broader participation from other majors such as communication, child life, and architecture. As a result, participation in the *Forum* class increased in diversity – ranging from the colleges that were represented, the backgrounds of the students, and the expertise of the visiting speakers. The diversity of values and backgrounds of students fuels lively discussions in the *Forum*, around focusing on the most significant problems and the best solutions to those problems; this mirrors the complexity of real-world problems. In addition, using a one-theme per semester approach, students are able to enroll in the course multiple times.

Increased and Integrated Community Engagement

Over the last six years, not only has there has been a deepening of community engagement in the *Forum* course (which directly correlates to our development of community partnerships) but its integration into the course has been more explicit. The COF's close proximity with a local natural resource (Muddy River) has spurred our collaboration with multiple community partners, ranging from NGOS, community groups, businesses, and federally mandated oversight groups. For example, the Emerald Necklace Conservancy (an advocate for the restoration of the historic landscape of the Emerald Necklace Park System of which the Muddy River is a part) has become a community partner working with COF students to organize and host the annual Earth Day Cleanup; in return, the Conservancy has participated in our annual Green Jobs Fair and Muddy River Research Symposium.

Another collaboration that has increased community engagement, and which developed early in the history of the *Forum* course, is the COF's partnership with the Maintenance and Management Oversight Committee (MMOC) of the Muddy River Restoration Project, a federally mandated oversight group for the $100 million restoration of the Muddy River. The excitement generated by this major environmental project naturally became the focus of the 2007 *Environmental Forum*. The integration of presentations by community experts on the special history and architecture of Fredrick Law Olmsted (the creator of the Emerald Park System) and on the water quality issues of the Muddy River enhanced student knowledge and interest in the topic. *Forum* students became engaged and conducted research projects on social and scientific aspects of the Muddy River, with the goal of providing their findings to the community partners. The Muddy River Research Symposium (MRRS) was created at this time to provide an annual opportunity for all stakeholders to share research, stories and opinions about this urban river. Over the last five years, this thoughtful use of community engagement has expanded student and community participation and involvement in the MRRS symposium, attracting students and faculty from the COF as well as local community partners (citizens, environmental groups, elected officials, etc.). Another way in which we have encouraged students to publicly present their community service projects with stakeholders is by matching the annual theme of the MRRS to that of the *Environmental Forum*.

Service-Learning

In addition to community engagement, *Forum* also integrates a service-learning component that encourages student and faculty interaction with local, regional, and national environmental advocates. As described by the Commission on National and Community Service (1990), service learning is a method that connects meaningful community service and academic learning, providing students with opportunities to use their newly acquired skills and knowledge. The benefits of incorporating service learning into higher education include: higher academic performance, increased civic responsibility and leadership abilities, and an increased awareness of the world (Astin et. al 2000). There have been numerous examples of service learning successfully applied in science (NSTA 2009), with environmental science providing one of the greatest opportunities for the incorporation of service learning (Leege and Cawthorn 2008).

At the inception of the *Forum*, the service-learning component consisted of a one day activity in which students focused on environmental topics. For example, collaborating with the Urban Wilds Initiative, students traveled to parks that were within walking distance from COF campuses and collected information that was later developed into promotional educational material. Service learning compromises a significant component (25-30%) of the Forum course and, as a result, we have been able to emphasize its importance over the years. By using a foundation of conversation (e.g., class discussions) and contact (e.g., field trips), we have been able to increase the number and quality of application (e.g., service learning) and collaboration (categories based on the GLISTEN Project typology of civic engagement in higher education). In addition, and perhaps most importantly, in the last couple of years, student interest in service learning has expanded to outside of the *Forum* classroom (e.g., working with college facilities departments to support sustainability efforts) as well as upon completion of the course (e.g., summer work with NGOs). This enhancement of learning outcomes can be seen in Table 2.

An important factor in increasing the rigor of service-learning pedagogy in 2010 was the involvement of the Scott-Ross Center at Simmons College, whose role is to integrate service-learning into courses at Simmons College. The Scott Ross Center provided a formal process of documentation for students, faculty, and community partners, such as service-learning contacts, a schedule, training, coaching, and a process to follow for students and faculty to insure student commitment and reflection. A formal final presentation and written reflections by students were required as part of this process. The community relationships developed by the Scott Ross Center over many years facilitated meaningful connections of the *Forum* students with community partners.

TABLE 2. Examples of service learning projects

Environmental Forum Theme	Year	Service Learning Component	Learning Outcomes
Muddy River	2007	Students either worked in research teams to examine the Muddy River ecosystem (e.g., animal biodiversity, tree distribution, water chemistry, etc.) or they organized COF student involvement in the Muddy River clean-up.	Students either worked in research teams to examine the Muddy River ecosystem (e.g., animal biodiversity, tree distribution, water chemistry, etc.) or they organized COF student involvement in the Muddy River clean-up. Students participated in the 1st Annual MRRS as well as the Muddy River clean-up.
Climate Change	2008	Students either worked in research teams to examine the Muddy River ecosystem or they organized COF student involvement in the Muddy River clean-up.	Students participated in the 2nd Annual MRRS as well as the Muddy River clean-up.
Sustainability	2009	Based on trips to other colleges that highlighted sustainability and interviews on their own campus, students developed recommendations for the best way to incorporate sustainability into their college.	Minor in Sustainability was adopted by Simmons College. Campus sustainability efforts presented by students in Forum. Continued participation in MMRS.
Environmental Health	2010	Students worked in teams on a number of community projects with public health officials (City of Boston), non-government organizations (YMCA), and local hospitals to apply what they learned in the Forum lecture/discussion in the real world.	Presentations in the Forum and MMRS, as well as reflection essays. In addition, several students continued to volunteer after the completion of the course at NGOs during the summer break.
Sustainable Energy	2011	Students worked on a variety of projects related to sustainability: such as participating in the "Power shift" march in Washington D.C., assisting an environmental film festival and fundraiser, teaching 6th graders about sustainable energy, and assisting Climate Change Brookline in a door-to-door green energy awareness campaign for the homeowner.	Several students presented on a sustainability panel as well as in breakout sessions at MRRS 2011. In addition, one student aided her college to gather information for an "environmental scan" of what options were preferred for the pursuit of sustainability for faculty and students.

Increasing variety of assessment tools

Initially, the only assessment tools repeatedly used in the *Forum* course program to measure learning outcomes for both content and personal engagement was the SENCER-SALG (Student Assessment of Learning Gains) survey and self reflections (Table 1). Because of the creation of this course using the SENCER vision, it was deemed critical that we focus on students' assessment and reflection of their own learning. A comparison of results for the SALG test showed that as a result of taking this course, students had greater personal confidence (Faszewski and Duggan, 2007). For example, students in the 2007 *Forum* had greater confidence in thinking critically and understanding scientific processes behind important scientific issues in the media (Table 3).

Over the years, depending on the faculty member, additional assessment tools (not noted in Table 1) may also have been used (e.g., standardized course evaluation questionnaires developed by their college). Although valuable feedback was obtained from these tools, faculty felt that the random addition of this variety of assessment tools did not provide a cohesive look at student learning in the Forum course over the years. For example, a tool to assess whether or not the students actually learned fundamental science concepts covered in the course was not required. To address this need, beginning in 2009, pre and post content assessments (e.g., quizzes) were implemented to assess these lower order learning outcomes. We also felt that it was important to assess the students' own self confidence and understanding of these terms in attempt to determine if they would feel comfortable enough with their newly acquired knowledge to actually apply it both in and outside of the Forum course. With this in mind, students were also given pre and post self assessments that listed the scientific terms and asked them to rate their understanding, from 0% ("never heard of it") to 100% ("I could explain that term

TABLE 3. SALG pre and post data on student personal confidence

	Pre-Test (N=16)	Post-Test (N=15)
Think critically about scientific findings I read about in the media	**3.19 (1.05)**	**3.93 (0.8)**
Determine what is—and is not—valid scientific evidence	**3.19 (0.98)**	**3.79 (0.70)**
Make an argument using scientific evidence	**3.31 (0.79)**	**3.93 (0.59)**
Understand scientific processes behind important scientific issues in the media	**3.06 (1.06)**	**3.80 (0.77)**

Values reported are the averages and standard deviations for student responses using a five-point scale where 5="Extremely confident" and 1="Not confident".

correctly to the class."). Analysis of the pre- and post- self assessments for *Environmental Forum* "Sustainable Energy" shows large increases in confidence in several topics current in the energy debate: especially, fracting for natural gas, shale gas, photovoltaic, peak oil and carbon sequestration (Table 4). Overall, student confidence increased from 41% to 74% on an average of all topics.

In 2010, through the use of the Scott Ross Center, enhancements were made to service-learning reflections. For example, "Guidance" questions prepared by the Scott Ross Center for Community Service at Simmons College helped students think more critically about their service learning experiences (Table 5). Student reflections indicated a high degree of engagement with the community partner and an appreciation of how service learning facilitated desired learning outcomes for the *Forum*. During the *Forum* that focused on Environmental Health, students worked with a wide spectrum of community partners: at Earthworks students worked to green urban spaces and primary schools in Boston; students worked with the City of Boston during lead paint inspections; at the Jamaica Plain Asthma/Environmental Initiative, students worked with children on asthma control; at the YMCA students interviewed immigrant families about different food options; students conducted the analysis of contaminated sediment in the Muddy River; and other students worked with the Bright Horizons Family Center to "green" a low income daycare center. Assessment of these activities included peer presentations and written reflections. It is believed that with the addition of these specific assessment tools, faculty is provided with a more comprehensive

TABLE 4. Pre and post self assessment of content (*Forum* Course focusing on sustainable energy)

Pre-assess	Post-assess	Change	Term
1	**83**	**82**	Fracking
6	84	**78**	Shale Gas
35	**91**	**56**	Photovoltaic
30	**84**	**54**	Peak Oil
13	**66**	**53**	Carbon Sequestration
10	**62**	**52**	Life Cycle Assessment
34	**83**	**49**	Cap and Trade
32	**76**	**44**	Decarbonize
42	**86**	**44**	Clean Coal
40	**80**	**40**	Externalities
7	**46**	**39**	Stabilization Wedge
19	**57**	**38**	IPCC
24	**61**	**37**	LEED
8	**44**	**36**	Precautionary Principle
41	**76**	**35**	Fuel Cell
52	**84**	**32**	Biomass
17	**42**	**25**	R value
73	**98**	**25**	Sustainability
61	**85**	**24**	BioFuel
28	**50**	**22**	Hat Pump
71	**89**	**18**	Sustainable Development
66	**84**	**18**	Carbon Cycle
73	**88**	**15**	Carrying Capacity
39	**54**	**15**	Anthropogenic
85	**99**	**14**	Renewable Energy
86	**99**	**13**	Greenhouse Gas
87	**96**	**9**	Ecosystem
19	**23**	**4**	Blackbody Radiation
86	**88**	**2**	Biodiversity

look, not only on students own self assessment, but also in regards to assessing content gained during the course relating to environmental topics.

Future Directions

Assessment of student learning has become an integral part of the *Forum* and will continue to be important as the student population and environmental topics change. We will include other assessment tools and metrics, such as those used by NSSE to measure engagement. In 2012, we look to increase

TABLE 5. Student reflections on service learning experiences

Guidance Questions	Reflection
Was this your first service-learning experience?	"This was the first service-learning project of this nature that I have participated in and I was very pleasantly surprised. Working with young children was a simple yet profound way to employ my developing knowledge and understanding of environmental sustainability."
How was this experience for you?	
How did the work you did with the community partner contribute to your learning in this class?	
What did you notice about the communities that you were working with for this project?	
What skills did you learn that you think you will be able to use in the future?	"I would definitely do another service-learning project. The project taught me how to use ingenuity in order to find workable and non-costly solutions. One cannot really learn about environmental health without seeing it firsthand."
Would you do another service-learning project for another class after this experience?	
Why do you think service learning is used with this course?	"What I have learned from my project could definitely have been learned without a service-learning component, but I think that enhanced my learning. My service-learning project greatly enhanced my understanding of Environmental Health."
Did anything surprise you about your placement?	
Do you think you could have gained the learning from your project in another way besides service-learning?	

TABLE 6. *Forum* Success Factors (Students' Point of View)

Success Factor	Students Comment
A variety of expert speakers bring their own and differing opinions to the Forum, exposing students to an authentic exposition of a complex problem.	"I liked hearing other peoples opinions because it gives insight and different perspectives on what we should be doing in terms of energy."
Students give presentations throughout the semester, formally debate issues, and are encouraged to participate.	"The [liked the] overall laidback atmosphere and encouragement to discuss, considering I came into the class not knowing much about sustainability."
Service-learning and community involvement projects were presented with clear rubrics for participation, assessment, and reflection.	"With service learning projects we were able to work hands-on with community leaders in promoting sustainability"
Speakers from different disciplines expose students to many different career options related to the Forum theme.	"I now am more aware of careers and direction I can take after graduation."
Encourage student engagement.	"Class discussions solidified and deconstructed arguments."

student engagement with community partners by arranging external co-op experiences and internships. Engagement of students with content, visiting speakers, other students, their college, and the community will continue to be an important goal. Those factors (Table 6) that have made the course a success for students will continue to be incorporated in the future. In addition, in order to maximize the relevance of the Forum to students, the focus each semester, although continuing to have an underlying theme of sustainability, will remain flexible enough to permit continued variety in environmental topics and formats not currently envisioned.

About the Authors

Michael Berger, Assistant Professor of Chemistry, Department of Chemistry and Physics, Simmons College. He was also the Director of the COF Center for Sustainability and the Environment, 2009-2011.

Jack Duggan, Professor, Department of Civil Engineering and Technology, Wentworth Institute of Technology. Duggan was also Director of the Colleges of the Fenway (COF) Environmental Science Program, 2005-2006.

Ellen E. Faszewski, Corresponding author: *Chair of the Math and Science Department, Associate Professor of Biology*, Wheelock College. Faszewski is also SENCER Leadership Fellow, a member of SCI-NE Leadership Council, and served as Director of the COF Environmental Science Program, 2007-2008.

References

Astin, A. W., Vogelgesang, L.J., Ikeda, E.K., and J.A. Yee. 2000. How service- learning affects students. Higher Education Research Institute. Los Angeles, CA.

Faszewski, EE and Duggan J. 2007. "*Environmental Forum*: The Cornerstone of a Joint Program in Environmental Science for the Colleges of the Fenway" Science and Civic Engagement, An International Journal, 1, 1, 19 – 23.

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

National and Community Service Act of 1990. Public Law 101-610, as amended.

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

PROJECT REPORT

Preparing Students for a Transdisciplinary Approach to Solving a Complex Problem

Traffic Issues in Los Angeles

Nageswar Rao Chekuri
Woodbury University

Zelda Gilbert
Woodbury University

Ken Johnson
City of Burbank, Public Works Department

Anil Kantak
Jet Propulsion Laboratory

Marty Tippens
Department of Mathematics and Natural Sciences, Woodbury University

Introduction

In addition to preparing students in disciplinary areas, universities must train them to become independent thinkers and to be capable of taking part in complex and collective activities outside their disciplines. Furthermore, students should be trained to extract knowledge from scientific practices and procedures, and integrate that knowledge with their disciplinary-specific knowledge to solve real-world complex issues. The training should consist of important mental activities such as analyzing the data to understand inter- and intraconnections; abstracting methods and techniques through analysis and synthesis; mentally organizing such procedures and techniques; and applying those to solve complex environmental and community issues.

This article examines the instructional approach and classroom activities used in the course on Traffic Issues in Los Angeles offered in spring 2008 at Woodbury University. This article also analyzes the students' work and SALG surveys to assess the course. As a part of the transdisciplinary practice, all the group members gathered on a common platform and generated a complex solution. The acceptance of different approaches and perspectives among all constituents to solving the traffic issues was not completely accomplished: partly because of the incommensurability of specialized languages in each of the fields of expertise and partly because of the coordinator's limited competence in moderation, mediation, and transferability to initiate and promote critical and constructive dialogues.

Instructional Approach

It is we who have created the academic disciplines and boundaries in an attempt to understand and tame "nature." If that is our goal, we need to transcend the artificial boundaries of our disciplines. No single academic discipline can fully uncover the interplay and interconnection of factors that underlie complex problems. Each discipline misses part of the point when considering the dynamics of a complex problem. An approach that consequently transcends artificial divisions of knowledge is important for higher education. The "transdisciplinary approach" combines different fields of knowledge to offer a larger and more-complete solution to complex problems (Kaufman et al. 2003). Nature does not manifest itself in the form of academic disciplines.

The Department of Mathematics and Natural Sciences offered the Traffic Issues course in Spring 2008. Four university professors—from mathematics, physics, psychology, and architecture—plus a research engineer from the Jet Propulsion Laboratory (JPL), and a traffic engineer from the city of Burbank Public Works Department were panel members in the course. The physics faculty member coordinated the class and acted as the facilitator. Ten students enrolled for the class, and eight finished. The prerequisites for the course were one 100-level academic writing course, one 200-level math course, one 200-level psychology course, one 200-level science course, and a 100-level public speaking course. The students possessed the required higher cognitive skills and background knowledge in mathematics, science, and psychology as well as the required basic communication and writing skills.

Students with common interests worked together as a group. They formed four groups and chose to write papers and give presentations on the following topics: traffic control systems for the twenty-first century; reorganizing Los Angeles: a transportation plan for Los Angeles to be rerouted; pollution; and Los Angeles integrated. Depending on the expertise required for each topic, each group worked closely with one or more of the panel members. The faculty members approached the issue from the perspective of their disciplines. The research engineer provided the cutting-edge expertise in the field of deep-space communication, and the traffic engineer provided practical experience, knowledge about government policies, and actual implementation expertise on day-to-day issues of the traffic in Burbank and Los Angeles.

The class had one introductory session, seventeen instructional sessions, three wrap-up sessions, two synthesis sessions, one field trip, one mid-term presentation session, one final presentation session, and one panel discussion session to discuss the options and solutions for the issue. At the first session, each panel member explained their expectations and plans for the course. The facilitator, who was also the physics expert, explained the learning outcomes and classroom procedures. Each panel member presented topics relevant to the traffic problem. Most topics were explained by more than one panel member. For example when discussing traffic flow, the mathematician presented a mathematical model for the traffic flow, the communications engineer showed how the flow can be further improved with the help of effective communication, and the traffic engineer explained the practical conditions, current statistics on the Sig Alerts, traffic jams, and limitations. After the psychologist described the psychological aspects of traffic issues, such as road rage and other human factors, the traffic engineer presented the statistical data about fatalities. Thus, the panel members team-taught most of the topics by complementing and supplementing the material of the other panelists. The coordinator, who was present for all sessions, presented summaries and discussed the procedure of analysis and synthesis during wrap up and synthesis sessions.

An ideal situation would have been that all panel members attended each session to understand the logic and procedures of other areas and to learn from other members. Panel members, however, were only able to teach their sessions and attend corresponding wrap-up sessions with the coordinator.

Each wrap-up session started with questions for the students to summarize the important points of the sessions, how those points related to the issue, and how they related to each other. In the wrap-up sessions, students identified how their independent learning, which included reading papers, out-of-classroom learning experiences, and so on, would help improve their understanding and approach to solving the problem. The panel members then presented their summaries and their opinions in light of the new data the students brought to the class. Students submitted weekly summaries to the panel member who conducted that week's session.

The synthesis sessions were initiated by asking the students to identify highlights, regularities, and patterns in each topic and between the topics thus far taught and their impact on the traffic issue. The coordinator wrote the students' ideas on the board and added more ideas. He further highlighted the important aspects of the ideas and connections between the ideas. In addition, he identified patterns, similarities, and differences and showed how to generate generalized procedures and techniques from the patterns.

All panel members were present during the midterm and final presentations and during the final panel discussions to give feedback to the students for further improvement.

When writing their papers, students needed to explain explicitly how the topics related to each other, how the topics related to the problem, and how the data they gathered during their research and literature survey lead to the proposed solution. They were asked to indicate how the topics contributed to their position or proposed solution. For the midterm paper and presentations, each group proposed a solution based on the topics covered to that time.

A student group and one of the five panel members formed as teams to generate a final solution. Students went to Burbank Traffic control room to witness the live traffic and signal control.

On the final paper, they modified their midterm solution in light of the entire semester's work. The final was performed in two stages: on the first day, the student groups presented their papers, on the second day, the student groups participated in a panel discussion.

Analysis of the Data

A SENCER-recommended inventory, Student Assessment of Learning Gains (SALG), was administered on the first and last days of the course. The students' final papers and SALG results were analyzed. Each panel member graded the summaries on the topics he or she taught. Equal weight was given to all the topics. The analysis and the results are presented here.

Criteria for Grading the papers

The criteria are represented with symbol (Cx.) C1 through C6 covering reasoning skills and transdisciplinarity, and C7 through C8 covering social-civic engagement.

- Recognizing the issues and its complexity (C1).
- Realizing the knowledge components (traditional: urban planning, communication, physics/science, psychology, and math; nontraditional: experiential knowledge from Burbank traffic engineer) necessary to address the issue (C2).
- Analyzing and synthesizing the knowledge components to understand the inter- and intrarelations between the chosen elements and their contribution to the problem (C3).
- Presenting new ideas, solutions, and concepts and applying the same to the problem (C4).
- Interpreting and evaluating the solutions (C5).
- Addressing society's problems in an informed manner (C6).
- Understanding the concept of the common good and who defines it (C7.)
- Participating in the social issue and practicing (C8).

Group Papers (Py). The group papers included:

- P1: "Traffic Control System for the Twenty-first Century"
- P2: "Reorganizing Los Angeles: A Transportation Plan for Los Angeles to be Re-Routed"
- P3: "Pollution"
- P4: "Los Angeles Integrated"

Figure 1 shows the grading scale used for the papers: 4 points = full task; 3 points= ¾ task; 2 points= ½ task and 1 point=1/4 task; and 0 points = no task. Two panel members read each paper.

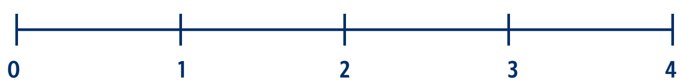


FIGURE 1. Grading scale for the papers.

When reading a paper, based on the meaning, each statement was categorized into one of the nine criteria (C1–C9.) Table 1 shows the frequency of each criterion in each paper.

TABLE 1. Number of occurrences (frequency) of each criterion determine a relative score on 0–4 scale.

Criteria \ Group Papers	P1	P2	P3	P4
C1	2	4	2	4
C2	1	2	1	3
C3	1	2	1	3
C4	2	3	2	3
C5	3	4	2	4
C6	2	4	2	4
C7	2	3	2	4
C8	0	0	0	0

Analysis of the Papers

Each group used knowledge from nontraditional sources. The groups covered three to five knowledge domains but no group covered all six areas. There is plenty of evidence that they analyzed, synthesized, and evaluated their solutions. All the groups presented inter- and intrarelations. The groups addressed societal problems in an informed manner with a focus on the common good. None of the groups indicated they were actively participating and practicing in the traffic-related issues. An analysis of the papers is presented below.

Paper P1: Traffic Control System for the Twenty-first Century. This paper used knowledge from four areas (psychology, communication, science, and the information the traffic engineer presented.) The paper discussed the communication to the traffic signals (macro), automation of the automobiles (micro), and their impact on pollution and psychological behavior of drivers. It suggested using smart/hybrid cars resulting in less pollution. It did not connect the issue to other areas discussed in the course. The effect of automation and traffic signals on the psychological behavior (intrarelation) of drivers was discussed. The paper also illuminated relations between the components involved in traffic-signal communication and automation (interrelations). The paper dissected the topics (traffic signals and automation) into small parts and illustrated the connections between those parts. Ultimately new ideas were generated and their benefits were discussed. The paper addressed one of the current societal issues (traffic) in an informed manner, and the common benefit of implementing the ideas was discussed.

Paper P2: Reorganizing Los Angeles: A Transportation Plan for Los Angeles to be Re-Routed. The paper discussed many areas affected by traffic flow but was less clear in explaining connections to the different disciplines presented in the course. The group realized the complexity of traffic issues and presented relationships between urban planning, psychology, knowledge from nontraditional sources, and global warming. Data was presented but not analyzed. Traffic communications were not discussed in the paper. The paper focused on the impact of urban planning, large mass-transit systems, stackable concept cars, and alternative energy sources. Psychological behavior, global warming, and the benefits to the individual and to society were discussed. Inter- and intrarelations were explicitly presented. For this purpose the information was broken into several parts, and all parts were synthesized into a group of suggestions. The benefits of these suggestions to society and to individuals were discussed (evaluating solution). The roles of government and public and private agencies were also discussed.

Paper P3: Pollution. The paper focused only on the pollution component of traffic. It used knowledge from three areas (science, psychology, and experiential knowledge.) The paper discussed general pollution, pollution inside the home, office, and schools, the types of gasses automobiles emit, and the emission of gasses based on fuel and type of vehicle. Statistical data was collected from various sources (from the information the traffic engineer presented in class and classwork.) The effect of pollution on the human body and the psychological effects were discussed. The paper examined the topics (pollution, the human body, and psychology) in small parts and examined the connections between those parts. Finally, new ideas were generated. The paper recommended smart cars to cut down emissions. The benefits of the new ideas were not fully discussed. Pollution was treated as a societal problem and was discussed in an informed manner.

P4. Los Angeles Integrated. This paper looked at traffic as an urban landscaping and infrastructure issue. The solution to traffic issues involved preparing an efficient urban plan and reworking the infrastructure around the urban plan. In the interest of efficiency, the paper proposed development along freeways, with homes built near business complexes. The proposal for infrastructure development was to create flexible freeways. More lanes would be open during peak hours for travel in one direction and the number of available lanes would change during the off-peak hours. Furthermore, lanes would be reallocated for different usage, such as public transit, carpool lanes, single-person lanes, and freight-transportation lanes. The paper presented a step-by-step analysis of urban infrastructure and proposed a general solution, followed by discussion. Additional topics included the density of traffic flow using the flow equation, presented with mathematical modeling. In order to change the attitudes and behaviors of citizens toward the use the public-transit systems, classical conditioning and other psychological methods were suggested. Statistics regarding population growth, the average number of commuters, and so on (given by the traffic engineer) were also used in the argument. The paper incorporated urban planning, mathematical modeling, physics, experiential knowledge, and psychology. The traffic issue was addressed in an informed manner with an emphasis on the common good.

Faculty graded final papers based on the following criteria:

- How well the proposed solution was explained
- How well class lecture and reading material was utilized to argue for the appropriateness of the proposed solution.
- How well the five areas of investigation were synthesized in the proposed solution.

Table 2 shows the scores the subject faculty awarded for each paper.

TABLE 2. Scores on each subject for each paper

Subject\ Group Papers	P1 (%)	P2 (%)	P3 (%)	P4 (%)
Architecture	82	85	72	89
Communication	60	70	60	70
Math	75	90	60	80
Physics	70	90	60	95
Psychology	85	90	94	85

Analysis of the SALG Results

The SALG had three components "Currently I feel I know," "Currently I feel I can," and "Currently I am interested in." These three components could be used to assess student's knowledge, confidence, attitude change and predisposition.

Transdisciplinary Skills and Confidence

Students' confidence in identifying the components in a complex issue such as traffic and in recognizing an issue as complex increased by about 67 percent. Furthermore, the results to the question "How can psychology assist in understanding the complex and interactive nature of the world?" showed a 64 percent increase, indicating that many students in the beginning of the class did not consider psychology as a contributing factor in understanding certain issues in traffic, but they realized its contribution by the end of the course. There was a 64 percent increase in realizing the need for collaboration to work on complex issues, but students' confidence in collaboration increased by only 20 percent. The confidence in analyzing a complex issue is increased by 8.8 percent. There was 40 percent increase in examining the traffic issue in a broader context (Question 3.3).

There was an 84 percent increase in the predisposition to reading traffic-related articles. Their confidence in understanding traffic-related articles raised by 43 percent. Their confidence in discussing the subject of traffic with friends and relatives increased by 38 percent, while their active involvement and acquiring jobs in the traffic related fields is poor (questions 3.4 and 3.5.) SALG survey contained questions related to Knowledge, Confidence,and Predisposition on skills and traffic issues. Table 3 shows percentage increase and Q x.x shows the corresponding question number in the SALG survey.

TABLE 3. SALG scores on Knowledge, Confidence and Predisposition

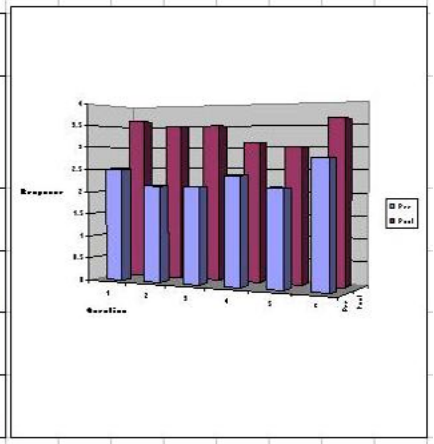
	Knowledge	Confidence	Predisposition
Collaboration on complex issues	Q1.2: **64.3**	Q2.5: **20**	
Design science experiments and reason through (creating new knowledge)	Q1.4: **31.5**	Q2.3: **42.5**	
Identify components in complex issues (comprehension)	Q1.6: **32**	Q2.1: **66.7**	
Analyze complex issue		Q2.2: **8.8**	
Reading articles and reason through	Q: 1.5: **40.8**	Q2.4: **42.6**	Q: 3.2: **84.0**
Giving oral presentations; finding articles		Q2.6: **16.0** Q2.7: **27.8**	
Discussing traffic with friends and relatives			Q3.1: **37.67**

NOTE: Q = question

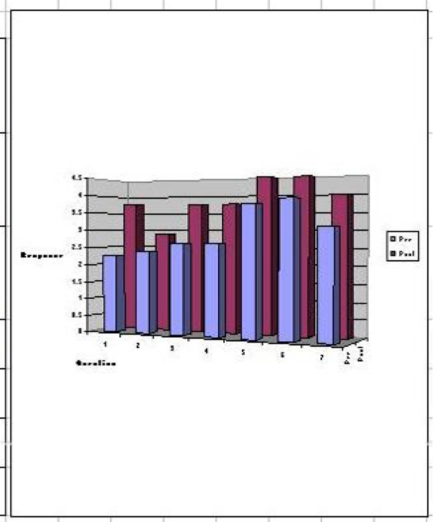
Statistical Analysis

A statistical analysis of the SALG surveys indicated that some specific learning gains were made. The greatest perceived learning gains are seen in questions 1.3, 3.2 and 3.3. In question

Currently , I feel I know	Pre	Post
1. How architects, engineers, scientists and psychologists think about problems	2.5	3.63
2. How experts from various disciplines such as Architecture, Physics, Psychology and experts from research and government organizations can work together to address a social issue.	2.13	3.5
3. How psychology can assist in understanding the complex and interactive nature of the world	2.13	3.5
4. How scientific experiments are designed and scientific reasoning is done	2.38	3.13
5. Articles in the media with scientific findings and/or reasoning	2.13	3
6. How to identify the components that influence a complex problem	2.75	3.63



Currently I feel I can	Pre	Post
1. Recognize a complex issue; the knowledge components (traditional and non traditional) necessary to address the issue	2.25	3.75
2. Recognize the inter and intra-relations between the components and their contribution to the issue	2.38	2.88
3. Design an experiment that involves the collection of data	2.63	3.75
4. Critically review articles	2.63	3.75
5. Work effectively with others	3.75	4.5
6. Give oral presentations	3.88	4.5
7. Find data or articles in journals or elsewhere	3.13	4



Presently I am interested in	Pre	Post
1. Discussing the subject of traffic with friends or family	3	4.13
2. Reading articles about the subject of traffic in magazines, journals or on the internet	2.38	4.38
3. Looking at the Topic in a broader context	3.14	4.38
4. Exploring career opportunities in this subject area	2.13	2.63
5. Joining a club or organizationin this subject area	1.75	2

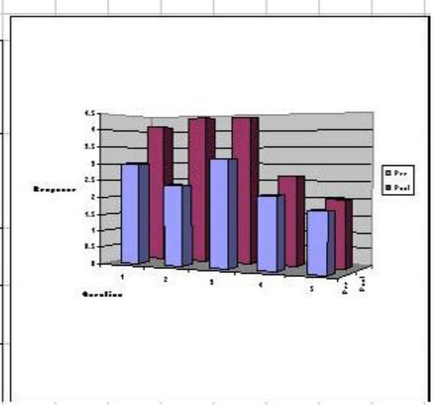


TABLE 4. SALG survey and pre-post results

1.3, students apparently had not considered the psychology of traffic prior to the class. This stands to reason, as most of the students had no requirement to take a psychology course in the architecture general education program. The large percentage increase in response to question 3.2, indicating high student interest in traffic articles following the course, may not have been entirely due to the course content. It had additional and compelling relevance due to gas prices increasing significantly during the semester.

A hypothesis test was performed on this data in an effort to determine whether the learning gains apparent in these responses were significant. For this we needed to determine which hypothesis test was appropriate. The "before" and "after" nature of the survey gave data in the form of paired samples. What was less clear was whether the Likert scale format used in the SALG instrument represented ordinal or interval data. We accepted the convention that considers the data to be ordinal. We also have a small sample of eight participants and do not know whether the sample comes from a normal distribution. For this situation, the Wilcoxon signed-rank test is appropriate. The Wilcoxon test has no requirement for a normal distribution but requires the data have a symmetric distribution. Looking at the aggregate data, we see the distribution of our responses in about half the cases is approximately symmetric. As is common in our small class of eight, there are many response distributions that are not symmetric at all. We will take note of this.

With the decision made on the appropriate test, we state the null hypothesis and alternative hypotheses.

$H_o: \mu_{Pre} = \mu_{Post}$,

the median responses do not differ in the pre- and post-SALG surveys.

$H_A: \mu_{Pre} \neq \mu_{Post}$,

the median responses differ in the pre- and post-SALG surveys. This is a two-tailed test. The data is entered into the SPSS program, and the Wilcoxon test performed. The SPSS output is posted in the Appendix. Those results pertaining to the acceptance or rejection of the null hypothesis are given under the title "Test Statistics" and the subheading "Asymp. Sig." The significance levels given by SPSS show that we reject the null hypothesis for all survey questions but 1.4, 2.2, 2.5, 2.6, and 3.5.

Data in 1.4, 2.2, 2.5, 2.6, 3.5 are among the nonsymmetric responses so we cannot rely on the test. Ultimately, with only eight students, this test is only valuable as an outline on how to proceed with future classes with greater enrollment. If classes of this type continue to be small, the data will continue to be less than conclusive, but a collection of the data from several sections of the same course could yield helpful results.

Solution

The transdisciplinary group came up with a general solution in three parts: urban planning, infrastructure, and education.

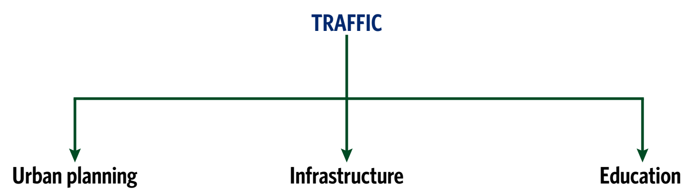


FIGURE 2. THREE PARTS OF TRAFFIC ISSUE

Urban Planning. The planning part was similar to the "garden city of to-morrow" (Howard 1965, 51). The purpose of Howard's plan was to sustain "a healthy, natural, and economic combination of town and country life" through a balance of work and leisure. The plan contained cluster of towns as shown in Figure 3. A town was to be built in an estate

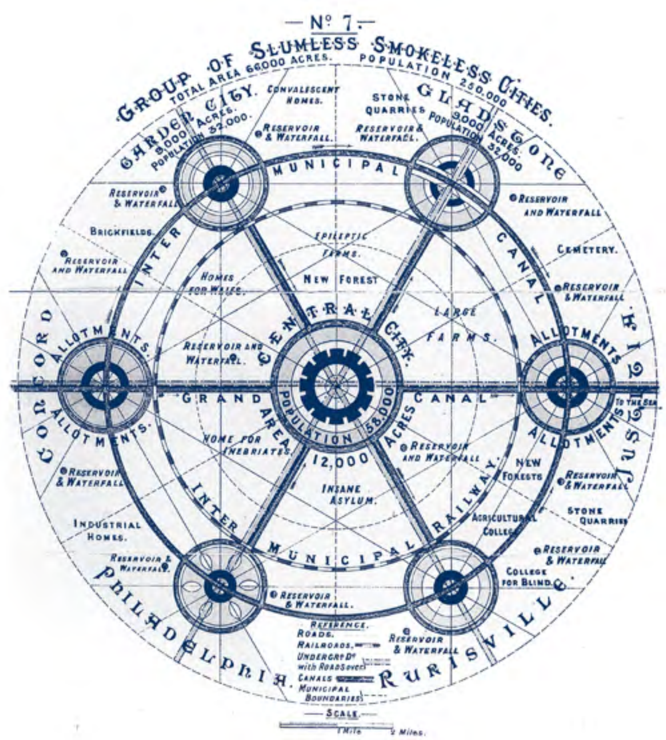


FIGURE 3.

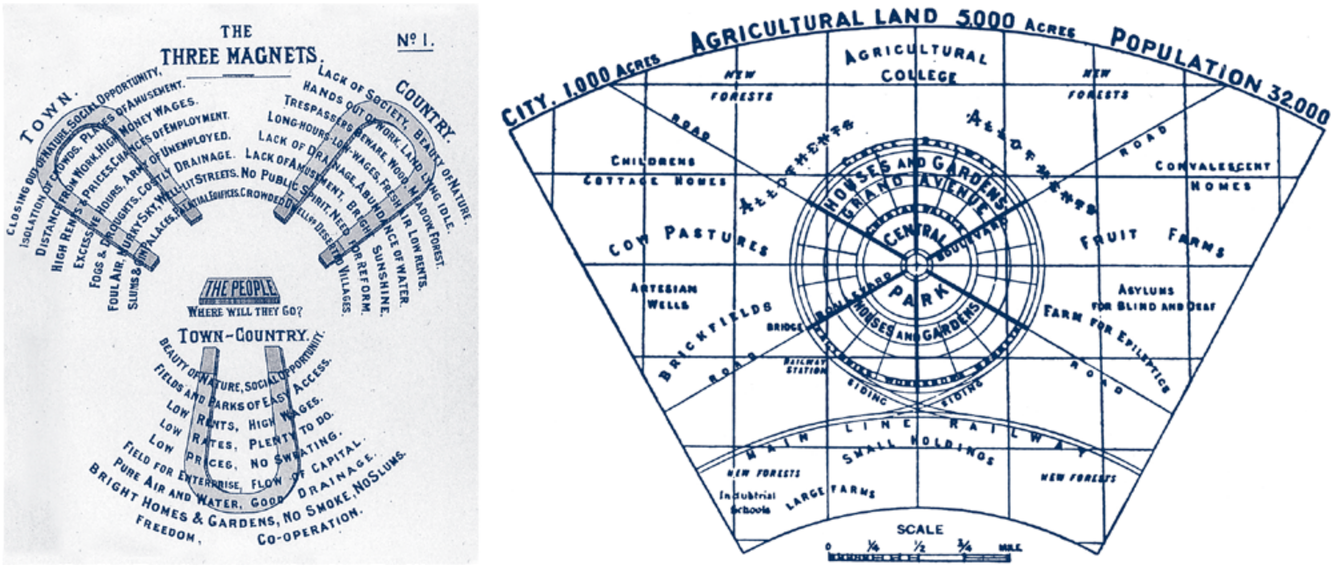


FIGURE 4. (left) A diagram of the Three Magnets, "in which the chief advantages of the town and of the country are set forth with their corresponding drawbacks, while the advantages of the Town-Country are seen to be free from the disadvantages of either" *Howard, 1965, p.16* (right) The Garden City, ground plan of the whole municipal area, *Howard, 1965, p.22*

with a park at the center of the estate as in Figure 4. Residences, businesses, and public buildings were to be in the park. Residences would be constructed for people of all the income brackets. The neighborhoods would be mixed, with the well-to-do and not so well-to-do living near one another. Factories and warehouses were to be built around the outer ring of the town with a circular railway lane in front of the factories and warehouses. There would be vegetable and flower gardens, wooded areas, and green parks throughout the urban area. An agricultural estate should be built around the warehouses. A wide glass arcade or crystal palace were to be built around the central park, as shown in Figure 5. This building was to be a favorite resort for people in wet weather. Six such towns

FIGURE 5.

were to be connected (see Figure 3). Six boulevards would connect these towns (Santa Monica, Culver City, Down Town, Long Beach, Valencia, Ventura, and Glendale) and would pass through the central part of the city.

Infrastructure. Highway planning, traffic signals, traffic flow, traffic signage, speed limits, automation, economics, energy considerations, and so on were discussed here.

The automation of traffic would have several advantages, including smooth traffic flow. The traffic control system (TCS) would have three parts—a central computing facility (CCF), substations (SS), and vehicles—each one installed with transponders that would have a unique identification number (TIN), as shown in Figure 6.

The CCF would have a master control and computing facility. This unit communicates with SS. CCF would make decisions based on the information received from SS and would send those decisions to SS. The SS would receive the information from vehicles and send it to CCF, would receive

FIGURE 6. Block diagram of the traffic control system.

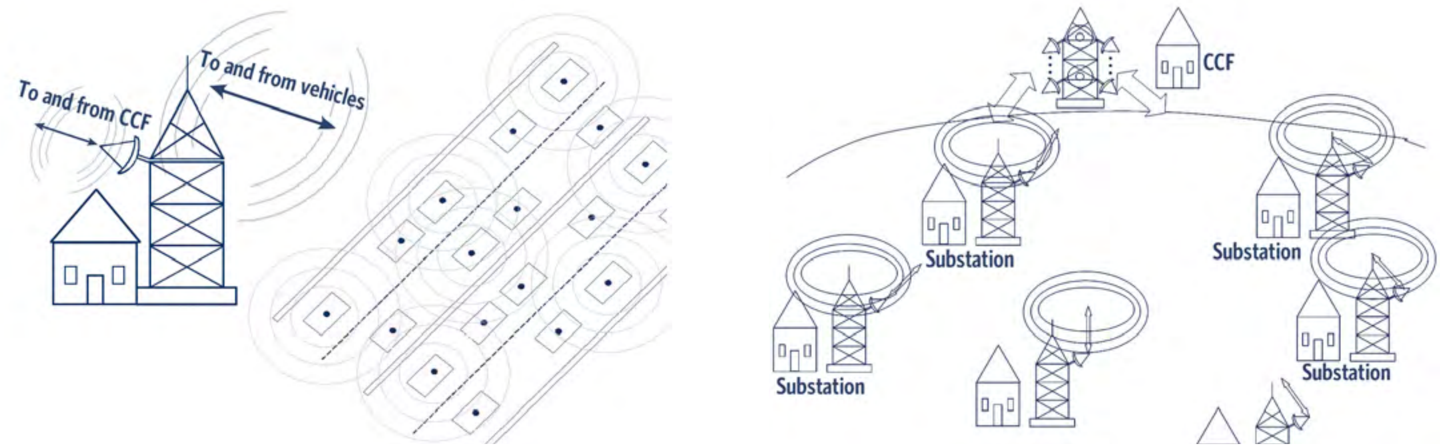


FIGURE 7 (a) Substation communicating with the vehicles on the highway. (b) CCF communicating with Sub stations that service an area.

the decisions from CCF and relay those to the vehicles. The city and county to be served by TCS would be divided into predefined sectors. The sizes of these sectors would depend upon the capacity of TCS to be installed as well as the number of vehicles on the roadways. Substations would be located in the service area such that each vehicle on any roadway would have a line of sight to three or more of the substations in the area as shown in Figure 7.

For safe driving, distance between subsequent vehicles should be computed using

$$x_f = s + x1 - NL - x_o$$

$$s = v\delta + \frac{v^2}{2d^f} - \frac{v^2}{2d_1} + NL + x_o,$$

where

$$x_o = \frac{v^2}{2d_1}$$

would be the leading vehicle breaking distance and

$$xo_f\delta = + \frac{v^2}{2d^f}$$

would be the following vehicle breaking distance; v would be the initial speed of the two vehicles; d_l would be the deceleration of the leading vehicle; df would be the deceleration of the following vehicle; d would be the reaction of the following vehicle; x_o would be the safe margin distance after stop; L would be the length of the following vehicle; and N would be the number of vehicles if there were more than two vehicles. All the vehicles would be moving with the same initial velocity.

A flexible freeway utilization system can be used for drivers depending on the time of the day. Lanes should be reallocated for different usage such as public transit, carpool, single-person vehicle, and freight transportation. The total lanes dedicated for the different modes of transportation should also vary throughout the day. Metro-rail lane should be built along each highway. In most cases, the rail lane should be built in place of the current divider and number one lanes of the highway

Stackable fuel efficient vehicles that run on solar and wind power can be used. The vehicles could be similar to the ones shown in Figure 8. Bike lanes can be developed on every major street for local mobility.

FIGURE 8. Stackable vehicles.

EDUCATION. Drivers should be required to take a course to cultivate good driving habits. The course should include topics on choosing better tires based on the type of vehicle; driving safely during wet and dry conditions, especially on curving roads; making the right decision when passing other vehicles; and psychologically handling road rage situations, such as when another driver pulls a gun or shows a middle figure, etc.

When driving on curved roads, the outer tires experience more force than the inner tires. To avoid a rollover, the tires should be chosen so that the traction (μ) will satisfy the following equation:

$$\frac{t}{2h} \leq \mu$$

where t is the distance between the tires on the same axle and h is the height of the vehicle's center of gravity.

The speed on such curved path should be

$$v = \sqrt{\frac{tgR}{2h}}$$

where R is the radius of the curved path and g is the acceleration due to gravity. Uneven distribution of the load in an SUV can also cause a change in the normal (N) force on the inner and outer tires. See Figure 9. As a result the SUV can roll over. An even distribution of the load is recommended. Traction would also decrease due to the softening of the rubber by the heat. The driver should take this into account when driving at higher speeds. When making a turn, the inner rear tire "cuts in" more than the inner front tire (by at least 1″). Drivers should leave enough space. Threaded tires would offer better traction in all the seasons. For normal driving the traction $\mu \approx .07$.

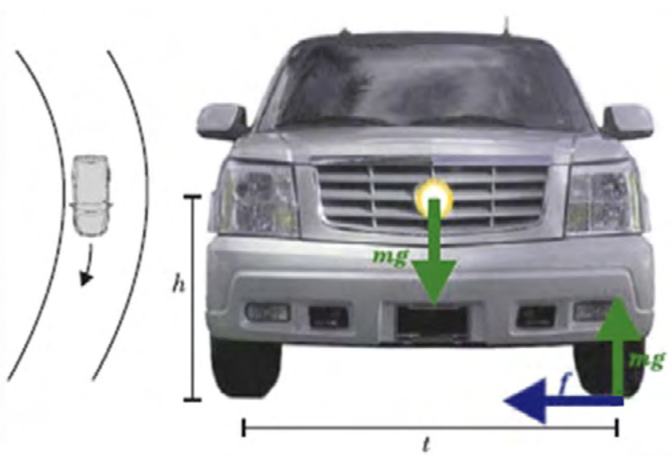


FIGURE 9. SUV on a curved road.

When passing a vehicle in front, drivers should make sure the oncoming vehicle is at a great enough distance from the their vehicle, as shown in Figure 10. The velocity of vehicle 1 relative vehicle 3 is

$$v_{13} = v_3 + v_1.$$

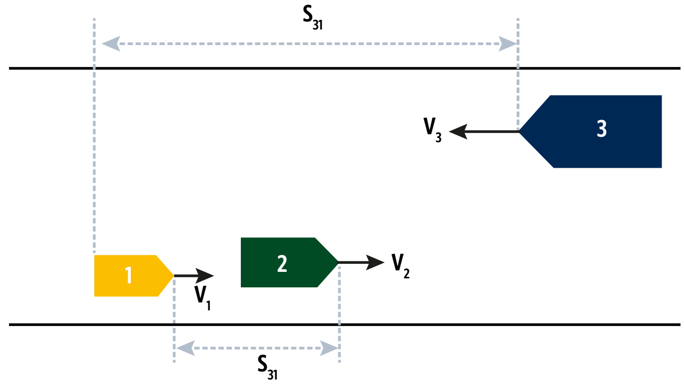


FIGURE 10. Vehicle 1 passing vehicle 2 at a safe distance.

The velocity of vehicle 1 relative vehicle 2 is:

$$v_{12} = v - v_1.$$

$$s_{21} = v_{12}t \quad \text{and} \quad s_{31} = v_{13}t.$$

Road rage is a popular term to identify acts of aggressive driving on the nation's roads. Aggressive driving includes behaviors such as passing on the shoulder, not yielding to merging traffic, speeding, and making rude gestures or shouting. (Interestingly, Los Angeles drivers are much less likely to describe these behaviors as aggressive compared to drivers nationally.) Psychologically, the path to aggression begins with frustration, which often leads to anger. When angry acts are repeated or returned by other drivers, aggression escalates, and acts of road rage happen. But it is not be the case with everyone. High-anger drivers are more vulnerable. For many drivers, their cars are an extension of the self. Aggressive acts directed at their car are thus directed at the driver and at his or her self-esteem. Environmental factors, such as noise levels, heat, loud music, air pollution, and congestion, are additional stressors, elevating the potential for aggressive driving. Though the incidence of psychopathology in those who express road rage was somewhat higher than in the general population, aggressive driving is generally not the result of a recognized disorder. Instead, it is derived from intense responses to incorrect beliefs that affect self-esteem. Cognitive Behavioral Therapy (CBT) can focus on those incorrect beliefs, challenge them, and show drivers how to respond in a more realistic and adaptive way to stressful situations. In the case of aggressive driving, incorrect beliefs might include:

FIGURE 11. Relaxation therapy teaches drivers to respond to the combative actions of other drivers by relaxing, rather than escalating the battle.

- Distortions of other drivers' motivations: "He cut me off on purpose!"
- Unrealistic goals: "I need to get to work at least five minutes faster than yesterday."
- Unrealistic roles: "It's my job to punish that driver who passed on the right."

Once these beliefs are identified, the driver can be taught to recognize antecedents and their consequences. For example, if allowing only thirty minutes to get to work is an unrealistic goal, the driver needs to allow forty minutes instead. Finally, relaxation therapy (RT) should also be included in attempts to reduce road rage (Figure 11). In RT, drivers learn to respond to the combative actions of other drivers by relaxing, rather than escalating the battle.

Results and Conclusions

A course "Traffic Issues in Los Angeles" was offered in spring 2008 at Woodbury University to prepare students on transdisciplinary approach to complex problems. The material used in the course is available in the Traffic folder on the university website. The members involved in the course were four faculty members (from mathematics, physics, psychology, and architecture), a research engineer in deep communications, a traffic engineer from the city of Burbank public works department, and ten students. The students had the required knowledge in mathematics, science, and psychology and the required skills in public speaking and writing. The faculty and the professional helped students analyze the traffic issue, apply the knowledge gained from the courses to this issue, and generate a general solution in a transdisciplinary way. The general solution to the traffic issues in Los Angeles have three components: urban planning, infrastructure and education.

The SALG results indicate that there was a general increase in the transdisciplinary skills and the confidence to adapt the approach. Students' general confidence in recognizing a complex issue and identifying its components increased by about 67 percent. Students had a 64 percent increase in realizing the need for collaboration to work on complex issues, but their confidence in collaborating increased by only 20 percent. Their confidence in analyzing a complex issue is increased by about 9 percent. There was a 40 percent increase in understanding traffic issues in a broader context. The results further indicated that the students' predisposition toward reading traffic-related articles increased by 84 percent, and their confidence in understanding such articles increased by 43 percent. Student confidence in discussing the subject of traffic with friends and relatives had increased by 38 percent. However the students' active involvement and acquiring jobs in traffic-related fields was poor.

Analysis of students' final papers showed that the students approached the problem in a transdisciplinary way but used only three to five knowledge domains. They analyzed, synthesized, and evaluated evidence to determine a solution to the problem. All the groups presented inter- and intrarelationships related to the traffic issue. Group one used knowledge from nontraditional sources and collaborated with both the engineers. Group two used knowledge from nontraditional sources and collaborated with the traffic engineer. Groups three and four used knowledge from nontraditional sources but did not collaborate with the other groups. All the groups addressed societal problems in an informed manner with an understanding of the common good. Group interaction was not measured systematically.

Improvements we hope for the next time we teach the course:

- Measure group interactions,
- Ensure students incorporate all the domains of knowledge in their problem-solving, and
- Begin with fewer domains of knowledge to ensure better manageability and to have students spend more time in synthesis and reflection.

About the Authors

Marty Tippens has been teaching mathematics for fifteen years and presently coordinates the Math Department at Woodbury University in Burbank, California. He received his masters in applied mathematics at California State, Northridge. He has presented at SENCER conferences in Chicago, Maine, and California on the application of civic issues to mathematics courses. He was also part of a team taught course addressing Los Angeles traffic from a transdisciplinary approach and presented with members of that team at the 2008 summer institute in Santa Rosa and at Woodbury's Fall 2010 SENCER symposium.

Zelda Gilbert is a professor of psychology at Woodbury University in Burbank, California. She received her bachelor's degree from Chatham College, her master's in clinical psychology from West Virginia University, and her doctorate in counseling psychology from the University of Kentucky. She also did post-doctoral study at UCLA in social psychology. She has worked in private practice but for most of her professional life has focused on teaching in areas such as Introduction to psychology, abnormal psychology, psychobiology, and statistics. She has worked on implementing the SENCER model in courses on addiction and on traffic issues in Southern California and has presented on both these at SENCER summer institutes.

Anil Kantak is currently an adjunct professor of mathematics and physics/astronomy at Woodbury University in Burbank, California. For more than thirty-five years, he has taught graduate and undergraduate telecommunications engineering, mathematics, physics, and other courses at universities such as University of Southern California, University of California at Los Angeles, Loyola Marymount University, Jet Propulsion Laboratory, and University of Washington, Washington D.C., West Coast University, and so on. He received his master's and doctorate in telecommunications engineering from the University of Southern California. He worked at the Jet Propulsion Laboratory (NASA) for thirty years in satellite communications for the deep space satellites and retired as a senior telecommunications systems engineer in 2011. He has published more than thirty-five papers in various technical journals such as the IEEE and authored five books in the area of telecommunications engineering.

Nageswar Rao Chekuri, received one of his masters in physics from Simon Fraser University in 1989 and doctorate in science education from the University of Cincinnati in 1996. He is a professor of physics and served as the chair. In the past he worked on solitons and fractional spins in the gauged o (3) non-liner sigma models with publications. His current research interests include application of physics principles to social and civic issues, learning theories, student learning and epistemologies, and transdisciplinary instructional approaches. He regularly presents papers and attends professional conferences.

Ken Johnson is the assistant public works director and traffic engineer for the Burbank, California, Public Works Department.

Acknowledgements

The authors would like to thank *Dr. David Rosen*, the Vice President of the Academic Affairs, for his support and encouragement.

References

Kaufman, A., D.M. Moss, and T.A. Osborn. 2003. *Beyond the Boundaries: A Transdisciplinary Approach to Learning and Teaching*. Westport, CT: Praeger Publishers.

Howard, E. 1965. *Garden Cities of To-morrow*. Edited by F.J. Osborn; with an introductory essay by Lewis Mumford. Cambridge, MA: MIT Press. http://www.library.cornell.edu/Reps/DOCS/howard.htm (accessed December 8, 2011).

http://mysites.woodbury.edu/personal/chekurir/Traffic/SitePages/Home.aspx (To open the traffic site copy and paste the link. Open Traffic, Open the folder, click for the dropdown menu, select "send to" down load a copy.)

PROJECT REPORT

Bio-Math Mapping:

Water Quality Analysis of Hudson River and Gowanus Canal A SENCER-based Summer Project

Urmi Ghosh-Dastidar
NYC College of Technology, CUNY

and

Liana Tsenova
NYC College of Technology, CUNY

Abstract

The aim of this project was to provide undergraduate students with the opportunity to perform interdisciplinary research, combining mathematics, microbiology and environmental studies, and to promote civic engagement. Students investigated the water quality of the Hudson River and the Gowanus Canal in New York City. Samples from different sites of the two waterways were collected and measured for total cultivable bacteria (TCB), fecal coliforms and *E. coli* and antibiotic resistant bacteria (ARB). Statistical analyses of the data were carried out. The results showed that the Hudson River had higher coliform counts than the Gowanus Canal, whereas the canal showed higher numbers of TCB compared to the river, most likely because of industrial pollution. Significant variations among ARB and *E. coli* along the Hudson shore indicated different level of human activities along the shoreline. A student assessment is included, indicating the success of the intent of this project.

Introduction

The Summer 2010 Bio-Math Mapping project, based on SENCER (Science Education for New Civic Engagements and Responsibilities) ideals, provided nine undergraduate students from New York City College of Technology of the City University of New York with the opportunity to study and perform interdisciplinary research, combining mathematics with epidemiology, microbiology and environmental studies. It met the SENCER ideal to *connect science and civic engagement by teaching through complex, contested current and unresolved public issues to basic science.*

A significant and unresolved environmental problem is the cleanliness of waterways. Human presence frequently causes adversarial impact in natural aquatic ecosystems. Preservation of natural biodiversity of recreational waters is important for preventing the growth and survival of pathogenic microorganisms. All waterways, in particular, recreational water bodies should be continuously monitored and, whenever necessary, preventive measures should be taken to avoid adversarial effects (Lobova 2008; Mallin 2000; Nevers 2007). One of the most widely used methods of monitoring environmental water quality is to measure the levels of enteric bacteria, most commonly and naturally occurring in human and animal intestines. The presence of enteric bacteria in aquatic environments indicates fecal contamination induced by human activities. The level of fecal coliforms present in water, including *E. coli*, is one of the most common measures of this type of bacteria (Coulliette 2009; Eaton 2005; Morgan 2003; Nevers 2007; Tortora 2010). Contamination by fecal coliforms is a major concern since their higher levels indicate the existence of human and warm-blooded animals' pollution and the presence of pathogens in the water (bacteria, viruses, etc.) (Alali 2009; Bergman 2009; Eaton 2005; Mallin 2000; Nevers 2007; Smith 2006; Watkinson 2007). Over time bacteria may adapt to the environment and acquire characteristics needed for survival, such as resistance to antibiotics (Drlica 2011; Lobova 2008; Tortora 2010). Antibiotic resistance is the capability of particular microorganisms to grow in the presence of a given antibiotic. There are several types of antibiotic resistance. One is called acquired resistance. Mutant cells arise either spontaneously (about one in a million cells) or from the transfer of resistance genes from other microbes (Drlica 2011). The resistance genes can be transferred via plasmid exchange (horizontal gene transfer by conjugation, transformation or transduction) and/or by reproduction (vertical transfer) (Drlica 2011; Tortora 2010). If a bacterium carries several resistance genes, relating to more than just one antibiotic, it is termed multidrug resistant (MDR).

Antibiotics are now frequently used in public health for the treatment and prevention of bacterial infections. A considerable amount of these antibiotics end up in the environmental waters by excretion, un-metabolized when consumed by humans or animals (Diwan 2010). Moreover, pharmaceutical plants also use the waterways as dumping grounds for unused antibiotics. As a result, bacterial populations are acquiring resistance to more and more antibiotics. Increasingly there is growing concern about antibiotic usage and the effects on resistance development and, consequently, on public health (Alali 2009; Drlica 2011; Fogarty 2007).

The Gowanus canal in Brooklyn, New York, once served as a major cargo transportation waterway. It is currently extremely polluted and poses a major threat to communal health. The proximity of several industrial sites, such as chemical plants, tanneries, concrete mixing facilities, and oil refineries pollutes the canal with various industrial wastes including coal tar and heavy metals like lead and mercury. The Environmental Protection Agency (EPA) recently added the canal to the *National Priorities List of its Superfund* program for further investigation (Navarro 2010).

In contrast, the water quality of the Hudson River, a major recreation water source, is *"generally acceptable."* (Associated Press 2008). However, many of the wastewater facilities built in the 1970s are crumbling now and unable to withstand extreme weather conditions. Sewage overflow or polluted storm water discharge into nearby waterways occurs after heavy rainfall either through cracks in treatment facilities, overflow valves or infrastructure failures. The release of pathogens, toxins, and other pollutants leads to a potential risk for safe recreational use of the Hudson River water body during this type of weather (Coulliette 2009; Michaels, 2008).

The pathogenic bacteria in the waterways can cause infections via the fecal/oral route of transmission or by direct contact. Treatment of these types of infections becomes more complicated when the microorganisms develop resistance to commonly used antibiotics. At present, the widespread use of antibiotics, both inside and outside of medicine, is playing a significant role in the emergence of resistant bacteria. Tetracycline is an antibiotic, commonly used to treat various types of infections in humans, such as Lyme disease, periodontal disease, chlamydial or rickettsial infections, acne etc. Moreover, it is used to promote the growth of livestock and fisheries. Contamination of water bodies by tetracycline resistant bacteria mostly occurs through human feces (Dotson 2008). Virginiamycin is an antibiotic primarily used in industrial farms not only to treat sick animals but also to offset the impact of crowding and poor sanitation, as well as to spur animal growth (Human Health and Industrial Firming). In fact, up to 70 percent of all antibiotics sold in the U.S. are given to healthy food animals (Clark 2000). Virginiamycin is one of the antibiotics, commonly used in livestock (poultry, swine and cattle) to prevent infectious diseases caused by bacteria, to decrease the amount of feed needed or to increase the rate of weight gain. Environmental contamination can occur either directly via livestock or when antibiotics are washed away from the feed following a heavy rainfall. Such consistent overuse of antibiotics may contribute to drug resistance development of intestinal bacteria. There are several recent reports on the effect of antibiotic resistance to Virginiamycin in the Hudson River (Benotti 2006; Furtula 2010; Palmer 2008; Wilson 2006).

The main goal of the present study was to perform comparative water quality analyses of two major waterways of

New York City. The microbiologic research aims were as follows:

1. To collect data on the total number of cultivable bacteria (TCB).
2. To determine the number of fecal coliforms and *E. coli* for the Hudson River and the Gowanus Canal.
3. To determine the antibiotic resistant bacteria (ARB) from the coliforms.

The mathematical objectives are presented below:

1. To compare the water quality of the Hudson River and the Gowanus canal using basic statistical tools such as measures of central tendency and standard deviations.
2. To perform regression analyses for finding possible associations between *E. coli* and ARB.
3. To analyze variations of *E. coli* and ARB obtained from coliforms among various locations of the Hudson River and the Gowanus canal, using chi-square test. Note that the samples are collected from six different locations for each waterway. The null hypothesis for each waterway is given below.

$H_{E.coli-o:}$ *E-coli counts independent of locations where E-coli counts obtained from coliforms*

and

$H_{ARB-o:}$ *ARB counts independent of locations where ARB counts obtained from coliforms*

At the end of the project term, the students had to prepare a complete written report with the microbiology results, statistical analysis and discussion on the environmental issues associated with the two waterways. Particularly, students were informed and provided literature on drinking water and recreational water testing guidelines. Our aim was to engage our students in solving multidisciplinary problems and answering civic questions by connecting knowledge in microbiology, epidemiology and mathematics, motivating students to pursue higher studies in an interdisciplinary field, particularly bio-math connected fields.

The project lasted four weeks and the participating students were all from the Applied Mathematics major except one from Computer Engineering. All nine students had taken two sequences of calculus, four students had linear algebra, four of them took differential equation, five students had an introductory statistics course and five students had at least one General Biology course. None of these students had prior knowledge in Microbiology (Figure 1).

FIGURE 1. In Front of Hudson, June 2010; From left to right: Philip Ajisogun, Prof. Urmi Ghosh-Dastidar, Prof. Liana Tsenova, Renne Clarke, YaPing Zhang, Tisha Brookes, Jodi-Ann Young (back), Steven Lora (back), Karmen T. Yu, YiMing Yu, and Jorge Paucar

Project Design and Methods

The project started with an introductory lecture describing the research goals, students' responsibilities, academic integrity, punctuality, and team work. Due to the interdisciplinary nature of this project, students were introduced to several topics of Microbiology and Statistics in lectures. The topics were:

- *The Microbial World and You*
- *Aquatic Microbiology and Sewage Treatment*
- *Introduction to Genetics and Antibiotic Resistance in Bacteria*
- *Water Purity tests and Lab Methods*
- *Safety Rules and Regulations for work in the Microbiology Lab.*
- *Measures of Central Tendency*
- *Data Presentation for Ungrouped and Multiple Data sets in Particular Medical Literature*
- *Probability of Counting*
- *Diagnostic Checking, Discrete and Continuous random variable, expected value*
- *Binomial distribution*
- *Hypothesis testing*
- *Chi-square goodness of fit test and test of independence*
- *Correlation and linear regression*
- *Evaluating the strength of the linear relationship.*

TABLE 1. Sites Sampled in the Hudson River

Site	Label
79th Street	H1
60th Street	H2
34th Street (at Javitz Center)	H3
Pier 62: Chelsea Pier	H4
Pier 45	H5
Battery Park City North	H6

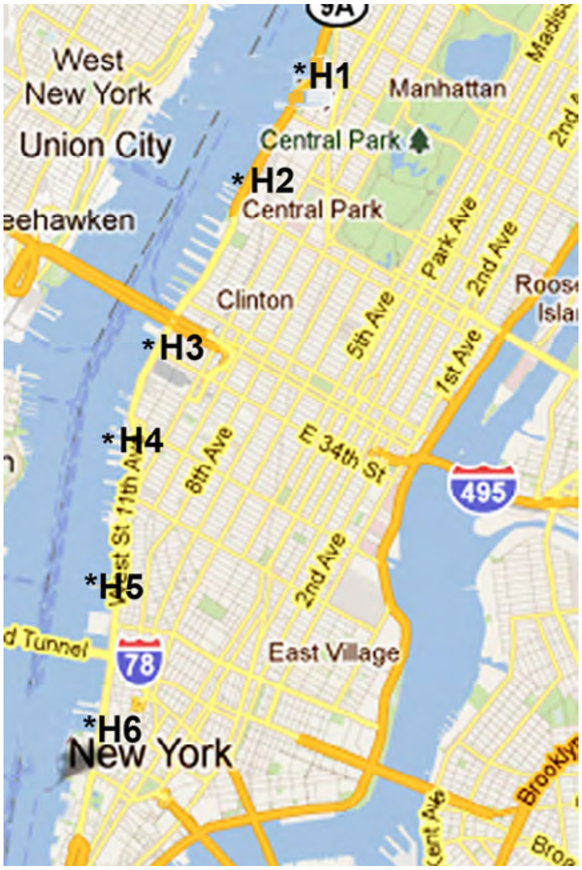


FIGURE 2. Hudson River Sampling Locations

Throughout these lectures, the bio-math connection was strongly reinforced by providing numerous applied example problems. Students were also introduced to Excel for efficient calculations and visual representations. Since the project lasted only four weeks, roughly the first two weeks were spent on orientation, introducing microbiology concepts, reviewing literature, collecting samples, and lab analysis. The second half of the project term was spent on teaching various statistical techniques, reviewing literature, data analysis, and writing technical reports.

TABLE 2. Sites Sampled in the Gowanus Canal

Site	Label
Degraw Street	G1
Carroll Street Bridge	G2
1st Street	G3
3rd Street Bridge	G4
9th Street Bridge	G5
12th Street	G6

FIGURE 3. Gowanus Canal Sampling Locations

FIGURE 4. Sample Collection from Gowanus Canal with Prof. Tsenova and Prof. Ghosh-Dastidar

On June 16, 2010, students collected water samples (200ml) from six different sites along the Hudson River in Manhattan (Table 1 and Figure 2).

FIGURE 5. SimPlates under UV light, for measuring Total Cultivable bacteria (TCB)

FIGURE 6. QuantiTray with large and small wells for measuring the number of coliforms; In the Microbiology Lab with Prof. Tsenova and Prof. Ghosh-Dastidar

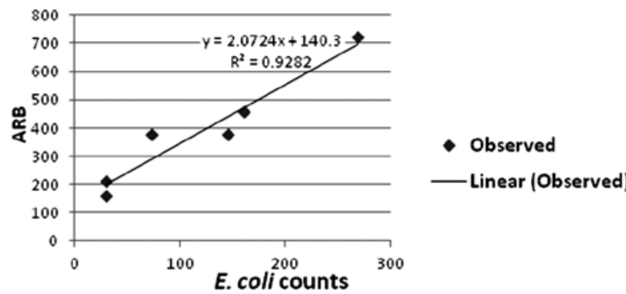


FIGURE 7. Regression line: Both estimates of ARB and *E. coli* are obtained from coliforms

On June 21, 2010 samples were collected from the Gowanus Canal in Brooklyn (Table 2, Figures 3 and 4).

Each water sample was poured into two sterile 100ml bottles (IDEXX Labs Inc., Maine, USA), which were then placed on ice to prevent the growth of bacteria. The samples were transported to the Microbiology Lab at the NYC College of Technology for testing. To determine the total number of bacteria in the water, the SimPlate Test® (IDEXX Labs Inc. Maine, USA) was performed. Ten-fold dilutions were used and the test was done according to the manufacturer's instructions. The samples were incubated at 350C for 48 hours. Then the plates were removed from the incubator and a UV light lamp was used to illuminate them. The number of fluorescent wells was counted and recorded (Figure 5). The Most Probable Number (MPN) (Maier 2009) of total bacteria was determined using a table provided by the manufacturer (IDEXX). The dilution factor was considered for the final calculation. QuantiTray Test® (IDEXX Labs Inc. Maine, USA) was used to determine the numbers of coliforms and *E. coli* (a main indicator for fecal contamination of the water). Ten-fold dilutions were prepared and the procedures were done according to the manufacturer's instructions. The QuantiTrays were sealed using a special sealer (IDEXX Labs Inc. Maine, USA), and placed in the incubator at 350C for 24 hours. After the appropriate time had elapsed, the trays were removed from the incubator and the number of yellow large and small wells was counted and recorded (Figure 6). The number of coliforms was determined using the manufacturer's table for MPN (IDEXX Quanti-Tray®/2000 MPN Table). Next, a UV light lamp was used to illuminate the tray, and the number of fluorescent wells counted and recorded as an indication of *E. coli*. The two selected antibiotics, Tetracycline and Virginiamicin were added to the medium to estimate the number of antibiotic resistant bacteria (ARB) (from coliforms and *E. coli*). The same method (QuantiTray Test®) was used. The obtained results for MPN of *E. coli* were compared to the guidelines and standards for recreational water.

Results and Analyses

A strong correlation was observed between the ARB population and *E. coli* counts (R2 ≈ 0.93, F-ratio = 51.72) (Figure 7) obtained from the Hudson River samples. Both of these estimates were obtained from coliforms. The presence of *E. coli* possibly influences the presence of ARB. Approximately 13.4% *E. coli* were ARB (median 9.4%) whereas about 2.6% coliforms were ARB (median 2.3%).

A chi-squared analysis (Milton 1999; Evans 2004; Nelson 2007) performed for both *E. coli* and ARB counts estimated from coliforms revealed that these counts are highly dependent on sampling locations of Hudson River ($X^2_{E\text{-}coli} = 263.135$; $X^2_{ARB} = 1849.91$; $P_{E\text{-}coli} < 0.001$; $P_{ARB} < 0.001$) i.e. the variations in

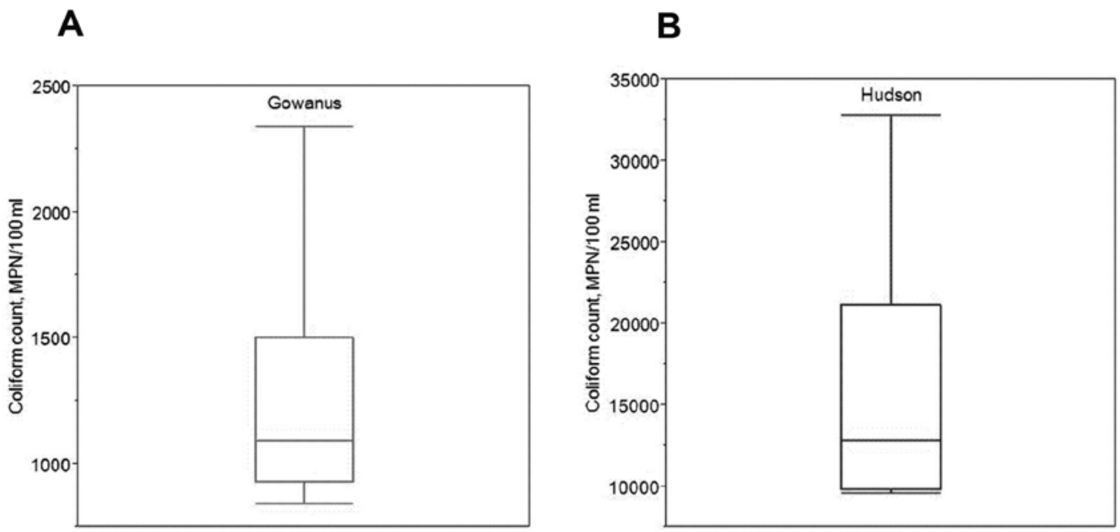


FIGURE 8. Box Plots for coliforms/100 mL. (A) Gowanus canal (B) Hudson River

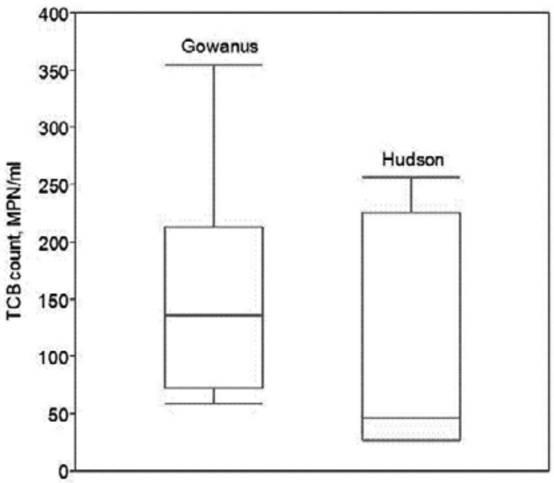


FIGURE 9. Box Plots for TCB/1mL for Gowanus canal and Hudson River

E. coli and ARB counts were too large to have occurred by chance alone. This fact probably can be justified by the various levels of human activities along the Hudson River shoreline.

Note that the regression analysis and chi-square test were not performed for the Gowanus Canal because of the relatively low numbers for *E. coli* and ARB obtained from the samples.

Our data set for the Gowanus Canal, showed lower average of coliforms in comparison with the data set for the Hudson River (Figure 8A and B). However, larger counts of TCB were observed in the Gowanus Canal compared to the Hudson River (Figure 9). The highest number of *E. coli* from the Hudson River was obtained from 79th Street (269 MPN/100ml). Comparatively lower counts were obtained from Pier 62, Pier 45 and Battery Park City North, indicating better water quality downstream.

The presence of higher numbers of coliforms in the Hudson River could be due to sanitation businesses, the many residential buildings along the shore line and the boats along the river or on the waterfront (Figure 10A). Another factor that could contribute to the higher numbers of coliforms is an overflow, usually occurring after a heavy rainfall, which introduces new bacteria from the mainland into the water (Coulliette 2009). In contrast, for the past several years the Gowanus canal has encountered a lot of industrial pollutants such as cement, oil, sulfur and heavy metals (lead and mercury) (Figures 10B and C). The increase in industrial waste and toxic materials present in the canal has decreased the oxygen levels and henceforth makes it difficult for any organism that requires oxygen to live and reproduce. This could explain the lower counts of coliforms found in the Gowanus Canal. In addition flushing tunnel and tide effects may bring fresh water in the canal. Although our one day sampling provided fewer coliforms in the Gowanus, other data suggests that the water quality of Gowanus Canal is often poor (Durkin, 2009). On the other hand, TCB are primarily environmental and more adaptable microorganisms, which may explain higher counts of TCB in the canal in spite of heavy pollution.

In our study, all water samples along the Hudson River had *E.coli* less than 235 MPN/100 mL based on the standards set for recreational water (Recreational Water Testing guideline), meaning that the water was good enough for recreational purposes (swimming, boating and fishing) at most places. Only the 79th Street sample provided *E. coli* counts of 269/100 ml, indicating further analysis required and possibly

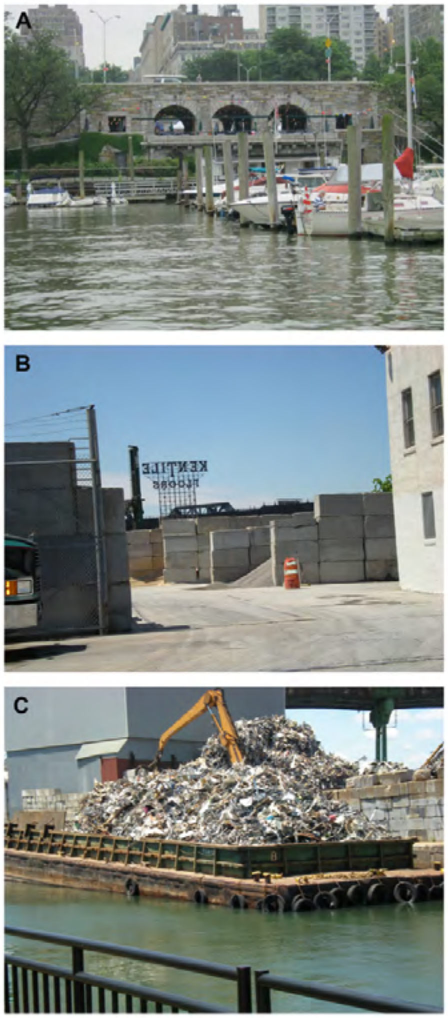


FIGURE 10A-C. (A) Hudson: Site 1, 79th St.
(B) Gowanus: Site 2, Nearby a Cement Plant
(C) Gowanus: Site 6, Debris

an advisory needed to be issued. It might be of interest to mention that one of the boat basins in Manhattan is located at this site.

Towards the end of the project, students were provided with a presentation, "What Next?" indicating different career opportunities available to them during or after their undergraduate studies. Students were informed about SENCER goals and ideals and various opportunities available in Environmental Protection Agency (EPA). The presentation also included information on different career paths, internships, and summer research opportunities in the mathematical-biology field, applied physical field, and graduate record examination. As indicated above, all participants were from an Applied Mathematics major except one, and all of them showed interest in pursuing higher-level studies.

Assessment and Students' Reflections

At the end of the project term an exit survey (IRB-approved) in a form of a questionnaire was administered to monitor and measure students' learning outcomes and their levels of satisfaction. Typical survey questions, relevant to this project, are presented below.

Six out of nine students responded to the following question: *List anything you feel you have learned or gained.* Responses:

- *I learned a lot about statistics and how they relate to the project. I also know more information about Microbiology.*
- *Microbiology*
- *T-test, Chi-square Test, Statistical Analysis*
- *A better understanding of interpreting data*
- *I have learned statistics, such as simple linear regression, box plot, chi-square, T-test, SD and correlation. I have learned Excel for all the math calculations; I have learnt much biology such as E. coli and coliforms. I have the experience of a research project.*
- *During this research project, I've learned the important topics in probability, which we used to analyze data. I've learned the overall knowledge about microbiology. I've learned how to write a report based on the results of our research.*

Seven responses came in answer to the question: *Which aspects of the project did you like the most? You can write more than one.*

- *The lab part and the math part.*
- *Aspects of this project I like the most are to obtain results and interpret the results from both scientific way and mathematical ways.*
- *Field Trips to collect data – Lab work (experiments, Sim Plate Test, Quanti Tray Test)*
- *Collection - Math analysis*
- *I like the statistics math part.*
- *The Collection (water samples)*
- *I like the fact that everyone interacted with each other and worked together.*

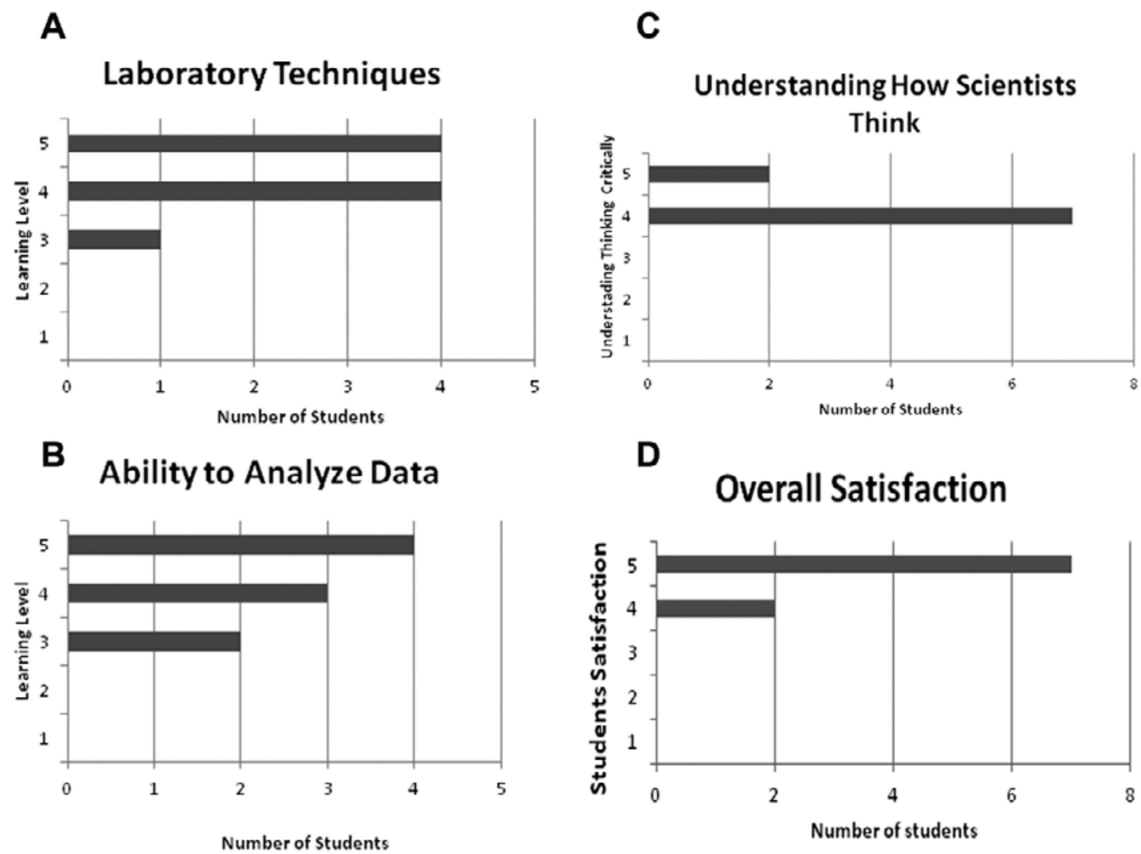


FIGURE 11 A-D (A), (B), and (C) – Scale: 5 = learned a substantial amount, 4 = learned quite a bit, 3 = learned to a moderate degree, 2 = learned a little, 1 = did not learn anything at all, NA = Not applicable (D) – Scale: 5 = Very satisfied, 4 = Somewhat satisfied, 3 = Neither satisfied nor dissatisfied , 2 = Somewhat dissatisfied, 1 = Very dissatisfied

To assess learning outcomes students were also encouraged to rate their experience on using laboratory techniques, data analysis, and understanding how scientists think. These three were administered with the following question.

> *Tell us what you have learned as a result of your research experience. Please rate the extent to which you feel you learned each of the following items as a result of conducting your research project.* For each item, the scale ranged from (1) did not learn anything at all to (5) learned a substantial amount.

Four of the nine reported they learned quite a bit (4) and four reported they learned a substantial amount (5) on using a microbiology lab. Three mentioned they learned quite a bit (4) and four informed they learned a substantial amount (5) on data analysis. Seven students reported they learned quite a bit (4) and two reported they gained substantially (5) on understanding how scientists think (Figures 11A, B, and C).

Students' overall satisfaction with this research is measured with the following question: Please rate your overall satisfaction with your research experience. The scale ranged from very dissatisfied to very satisfied.

Seven reported they were very satisfied with their overall research experience when two students were somewhat satisfied. A summary of these responses is presented below (Figure 11D).

The success of the research project is best conveyed by the students' reflections on their overall impression of the summer research. Three are presented below:

> *My research experience this summer was fun! This was my first math based research and I like the whole interdisciplinary thing. I wish we had more time and resources to do more. I got to see the stuff learned in the classroom, applied in real life. It was actually really cool seeing these practical uses. It made the concepts clearer, solidifying their meaning. We had two passionate mentors, whose enthusiasm rubbed off on me. And my colleagues were fun to be around and eager to get their work done.*

The summer research program was a wonderful experience, one that I enjoyed very much. I very much appreciated the field experience, going out to collect data. Also, I enjoyed the lab analysis and microbiology aspects of our project. Prior to our research project, I was not aware of the pollution in the Hudson River and the Gowanus Canal. I was aware only that they were not safe to swim in. Hence the program has offered me insight in my environment, particularly the water bodies of NYC. During the program I also learned statistical analyses Chi-Square Test, Correlation (Regression) Analysis and how to do Box Plots.

This summer research provided me a chance to learn and to touch upon topics in statistics in advance since I haven't taken that class yet. In this summer research I learned how to effectively use statistics equations and the box and whisker plot to analyze data. This research also provided me a chance to learn about microbiology. This research helped to introduce me to new knowledge of math and microbiology. My overall impression of this summer research is that participating in a research project not only means to perform experiments or to analyze data, but is also to learn and to explore new knowledge. In order to accomplish a goal within a short amount of time during summer research requires a lot of teamwork and communication between everyone in the research group. This is the first research that I've participated in my college life. This experiment taught me a lot.

Conclusion and Future Direction

The strong correlation found between ARB and *E. coli* suggests that the antibiotic resistance is probably influenced by *E. coli* in the water. A single sample analysis of the Hudson River indicated good quality of the water in most of the sampling locations except at 79th Street, where the *E. coli* counts exceeded the acceptable 235 MPN/100 mL, meaning further analysis should be performed. A statistically significant difference was observed for *E. coli* and ARB counts among the various Hudson River locations most likely due to different levels of human activities along the Hudson River. Our one day sampling of the Gowanus Canal did not indicate higher coliform counts than that of the Hudson River. However, it showed higher counts of TCB than the ones found in the Hudson River. Due to inadequate oxygen supply and pollution, the conditions of the Gowanus Canal may not be

FIGURE 12 City Tech students at MathFest with Prof. Ghosh-Dastidar, Pittsburgh, August 2010

favorable for the growth and survival of coliforms. Compared to them, TCB are mainly environmental bacteria, more adaptable to various conditions.

As a whole, we consider the summer project very successful. Our aim was to combine different subject areas, such as epidemiology, microbiological tests for water quality and statistical analyses, to address serious environmental questions such as standards and monitoring of drinking and recreational water, potential sources of pollution of the Hudson River and the Gowanus Canal, and to motivate the students to pursue research and more advanced studies. Over all, we found that the students were very enthusiastic and eager to learn. The interaction with them was easy and pleasant. They worked very well as a team while collecting the water samples, while working in the microbiology lab and in the computer lab. They also assisted each other during mathematical problem solving sessions, writing reports and prior to the conference presentation. At the end of the project term, students submitted their individual reports, showing great creativity and accuracy in interpretation. Students presented their work in August 2010, at the MathFest in Pittsburgh, an event organized by the Mathematical Society of America (MAA) (Figure 12). In September 2010 Jodi-Ann Young made a presentation at the Peach State LSAMP 5th Annual Fall Symposium & Research Conference at the University of Georgia in Athens, GA and received the second prize. During the summer of 2011 four out of these nine students applied for summer research opportunities for undergraduates and all four were accepted as REU (Research Experience for Undergraduates) students in the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) at Rutgers University, NJ. Two students already graduated with Applied Math majors and one of them is pursuing graduate studies.

In conclusion, we consider the Summer project of 2010 very sustainable and we plan to offer similar research opportunities to student majoring in Applied Mathematics but also to students interested in pursuing a degree in Biological and Environmental sciences.

Acknowledgements

We wish to express our gratitude to Prof. Aaron Barlow and Prof. A.E. Dreyfuss for their valuable comments. We thank Dr. Pamela Brown, Dean of School of Arts and Sciences, NYCCT, CUNY for funding this project through NSF DUE grant #0622493 and for her continuous support; Dr. Janet Liou-Mark for assisting with student selection; William Dungey, Senior Environmental Account Manager, and *Sharon Muhilly*, Technical Support from IDEXX Laboratories for their assistance with the equipment and valuable suggestions; Mr. Christos Tsiamis, Project Manager, Central New York, USEPA for his consultation. We also thank the New York City Louis Stokes Alliance for Minority Participation (NYCLSAMP) for providing support. Finally, we acknowledge all of the student participants for their enthusiasm and eagerness to learn and for their excellent performance. Alphabetically these students are Philip Ajisogun, Tisha Brookes, Renee Clarke, Steven Lora, Jorge Paucar, Jodi-Ann Young, Yi Ming Yu, Karmen T. Yu, and Ya Ping Zhang.

About the Authors

Urmi Ghosh-Dastidar (ughosh-dastidar@citytech.cuny.edu) is the Director of Liberal Arts and Sciences Advisement and an Associate Professor of the Mathematics Department at New York City College of Technology – City University of New York. She received a Ph.D. in Applied Mathematics from New Jersey Institute of Technology and a B.S. in Applied Mathematics from The Ohio State University. Her current interests include optimal control problem in epidemiology, biological applications of graph theory, and developing and applying bio-math related undergraduate modules in various SENCER related projects. She has been elected as a SENCER leadership fellow by the National Leadership Board of the National Center for Science and Civic Engagement for the current year.

Liana Tsenova is currently assistant professor at the Biological Sciences Department, New York City College of Technology – City University of New York. She has earned her M.D. and specialty in Microbiology and Immunology from the Medical Academy in Sofia, Bulgaria. She received her postdoctoral training at the Rockefeller University in New York. For 18 years she has been working in the field of immunology of tuberculosis and other infectious diseases. Her current interests lie in collaborative interdisciplinary projects with undergraduates, combining microbiology and mathematics to address epidemiologic, ecologic and health care problems.

References

Alali W.Q., H. M. Scott, H.M., Christian, K.L., Fajt, V.R., Harvey, R.B., Lawhorn, D.B. 2009. "Relationship between level of antibiotic use and resistance among Escherichia coli isolates integrated multi-site cohorts of humans and swine". *Preventive Veterinary Medicine*, 90: 160-167.

Associated Press. July 24, 2008. "Study shows Hudson River is Mostly Safe for Swimming". http://www.nj.com/news/index.ssf/2008/07/study_shows_the_hudson_river_i.html (accessed July 28, 2011).

Bergman et al. Mar, 2009. Association between Antimicrobial Consumption and Resistance in Escherichia coli, Antimicrobial Agents and Chemotherapy, 912-917.

Benotti et al. 2006. "Occurrence of pharmaceuticals in shallow ground water of Suffolk County, New York, 2002-2005." U.S Geological Survey Open File Report 2006- 1297, 5 pages, online only.

Coulliette et al. May 15 2009. "Space/Time Analysis of Fecal Pollution and Rainfall in an Eastern North Carolina Estuary." Environ Sci Technol. 43(10), 3728–3735.

Diwan et al. 2010. "Antibiotics and antibiotic-resistant bacteria in waters associated with a hospital in Ujjain, India." BMC Public Health, 10. Available online: http://www.biomedcentral.com/1471-2458/10/414.

Drlica, K and D.S. Perlin, 2010. Antibiotic Resistance: Understanding and Responding to an Emerging Crisis." Pearson Education, Inc., FT Press, New Jersey.

Dotson D. S. May 21 2008. "Factors that Influence the Distribution of Antibiotic Resistant Bacteria in the Mud River, WV." Thesis submitted to the Graduate College of Marshall University.

Durkin E. June 11, 2009. "Unsafe sewage levels in canal bacteria count high in Gowanus." Daily News.

Eaton et al. (Editors) 2005. American Public Health Association. "Standard Methods for the Examination of Water and Wastewater." Centennial Edition. 21. Baltimore, Maryland.

Evans M.J. and J.S. Rosenthal, 2004. Probability and Statistics the Science of Uncertainty, W. H. Freeman and Company, NY.

Fogarty et al. 2007. "Antibiotic-Resistant Fecal Bacteria, Antibiotics, and Mercury in Surface Waters of Oakland County, Michigan, 2005-2006." USGS, Scientific Investigations Report 2007–5242, U.S. Department of the Interior, U.S. Geological Survey.

Furtula et al., Jan. 2010. "Veterinary pharmaceuticals and antibiotic resistance of Escherichia coli isolates in poultry litter from commercial farms and controlled feeding trials." Poult Sci. 89(1), 180-188.

Gerhardt, Murray (editor in-chief), Wood, and Krieg 1994. "Methods for General and Molecular Bacteriology, American Society for Microbiology." Washington, D.C.

The PEW Charitable Trusts. "Human Health and Industrial Farming." http://www.saveantibiotics.org/ourwork.html (accessed July 28, 2011).

IDEXX Quanti-Tray®/2000 MPN Table. http://www.epi-net.org/eng/past_conf_files/indicators_conf_08/MPN%20table.pdf

Lobova et al. (2008). "Multiple antibiotic resistance of heterotrophic bacteria in the littoral zone of Lake Shira as an indicator of human impact on the ecosystem." Microbiological Research 163, 152 – 160.

Maier et al. 2009. Environmental Microbiology, 2nd ed. Academic Press, NY.

Mallin et al. 2000. "Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds." Ecological Applications 10(4), 1047–1056.

Michaels C. 2008. "Swimmable River: Towards Better Quality Water Monitoring in the Hudson River Estuary." http://www.riverkeeper.org/wpcontent/uploads/2009/06/Swimmable_River_Report_final.pdf. (accessed July 28, 2011).

Milton J. S. 1999. Statistical Methods in the Biological and Health Sciences, 3rd ed., WCB McGraw-Hill, NY.

Morgan et al. Jan-Feb. 2003. "Enumeration of Waterborne Escherichia coli with Petrifilm Plates: Comparison to Standard Methods." J. Environ. Qual. 32, 368 – 373.

Navarro M. The New York Times. N.Y. /Region. March 2, 2010. "Gowanus Canal Gets Superfund Status." http://www.nytimes.com/2010/03/03/nyregion/03gowanus.html (accessed July 28, 2011).

Nelson K. E. and C. F. M. Williams, 2007. Infectious Disease Epidemiology Theory and Practice, 2nd ed., Jones and Bartlett Publishers, Boston, 2007.

Nevers M. B. and R. L. Whitman, 2007. "Nowcast modeling of Escherichia coli concentrations at multiple urban beaches of southern Lake Michigan." Water Research 39, 5250–5260.

Navarro M. March 2010. "Gowanus Canal Gets Superfund Status." The New York Times. N.Y. /Region. http://www.nytimes.com/2010/03/03/nyregion/03gowanus.html (accessed 28 July 2011).

Palmer et al. 2008. "Sources of pharmaceutical pollution in the New York City watershed." Science of the Total Environment. 394, 90-102.

Recreational Water Testing (last update Oct 17, 2008). Environmental Health Division http://www.slh.wisc.edu/ehd/watermicro (accessed July 28, 2011).

SimPlate® for HPC Unit Dose. (2009 ILaboratories Inc.). http://www.idexx.com/pubwebresources/pdf/en_us/water/simplate-for-hpc-unit-dose-insert.pdf. (accessed July 28, 2011).

Smith L. M. 2006. "Antibiotic Resistant and Coliforms Bacteria in the Ohio River; 2002 to 2004." M.S. Thesis, Marshall Univ.

Tortora et al. 2010. Microbiology: an Introduction, 10th Ed, Pearson Education, Inc., San Francisco, CA.

Watkinson et al. Sept. 2007. "Antibiotic-Resistant Escherichia coli in Wasterwaters, Surface Waters, and Oysters from an Urban Riverine System." Applied and Environmental Microbiology, 5667-5670.

Wilson, L. et al. Jun 13, 2006. "A survey of the New York City Watershed for the presence of pharmaceuticals." Bureau of Water Supply Protection, Center for Environmental Health, New York State Department of Health, Troy NY. Biggs Laboratory, Wadsworth Center, New York State, Department of Health, Albany, NY.

PROJECT REPORT

Learning Public Health Through Civic Issues

Kathleen FitzPatrick
Merrimack College

Abstract

This course is organized around current challenging health issues, such as mandatory immunization, childhood obesity, health insurance, tobacco control, etc. Activities included issues-focused debates, lecture and video presentations, case study discussions, and guest speakers. Students completed fifteen hours of community-based service learning, many in the Lawrence Math-Science Partnership, an outreach program in which undergraduates work on after-school STEM enrichment activities with middle-school students. Several activities complemented the course issues, allowing college students to make connections between course theory and community needs, while engaging middle-school students in important public health concepts. The SENCER-SALG assessment (N=189/192 (98%) of enrolled students) indicated that the course was of much/great help for learning in addressing real world issues (80%), looking at the interplay of science and civic issues (71%) and in the service learning activities (53%). 58% of students indicated good/great gains in their interest in volunteering for science-related community service.

Introduction

In 2008, Merrimack College adopted a four credit per course curricular model. At this time, major curricula were completely redesigned. Our Department recognized that since many of our students intend to pursue careers in health care, knowledge of population medicine and health care system organization and function was critical. This content was not included in the major program previously. The Association of American Colleges and Universities (AACU, 2007) recommends that education in public health is essential for all undergraduates, in preparing an engaged citizenry for civic responsibility. Public health, a highly interdisciplinary and applied field, offered an opportunity to design an entirely new course using the NSF Science Education for New Civic Engagements and Responsibilities (SENCER) principles of science education through engagement with complex, unresolved civic issues. One of the goals of SENCER is to "strengthen students' understanding of science and their capacity for responsible work and citizenship." (SENCER, 2011). A faculty team attended the SENCER Summer Institute in 2009; this experience provided guidelines for designing this new course. (Tewksbury and MacDonald, 2005). Additional guidance in specific content came from AACU public health curriculum recommendations (Riegelman and Albertine, 2008).

The goals of this course were 1) to teach the basic principles of public health by focusing on several current, complex and challenging public health issues, and 2) to include a required service learning experience, as the added value fourth credit, that would place students in health-related field sites where they could connect classroom content to actual experience, and 3) to employ a variety of active learning techniques to cultivate student engagement. The hypothesis was that this approach would generate positive attitudes toward and engagement with civic issues, while achieving the learning goals. A three year assessment of the course, using the SENCER version of the Student Assessment of Learning Gains (SALG; http://www.salgsite.net; Seymour et al., 2000) is presented below. Student reaction to the issues focus and engagement components was quite positive. Preliminary findings from the first year have been presented (FitzPatrick, 2009).

Methods

Context of the Study

Our institution is a small (2000 student), private, comprehensive college. Data are reported here for 192 students (29% male, 71% female) enrolled in Community Public Health in 2008 (sixty-six total, two sections), 2009 (sixty-six total, two sections), 2010 (sixty total, two sections), all taught by the author. The course is required for all majors in Health Science, Sports Medicine and Athletic Training. These students were almost all traditional college age students and predominantly in their sophomore year. The Merrimack College Institutional Review Board approved this study.

Course Description

HSC3302 Community Public Health Four credits This course will aim to understand the distribution and determinants of health and disease, injury, disability and mortality within populations, with the goal of prevention and health promotion, through changes in individual behavior, control of infectious disease and environmental health factors, and social and political organization for health improvement.

Learning Objectives

The course content, activities and assessments were designed to help students achieve three advanced learning objectives (Table 1). These are higher order skills at the analysis/synthesis levels of learning, but they require mastery of basic objectives to complete. In addition, there were thirteen basic content learning objectives, appropriate for a

TABLE 1. Community Public Health Learning Goals Performance and Perceptual Assessment 2008-2010 N = 192

	Performance Assessment Mean(sd)		SALG Perceptual Assessment Mean(sd) 5 = High
ADVANCED LEARNING OUTCOMES			
Analyze a new public health problem by applying the public health approach of problem, cause, intervention and implementation/assessment.	Service Learning Reflective Journals	92.1 (6.5)	4.2 (0.9)
Evaluate the quality of public health information on the Internet or in mass media.	Homework Papers	94.6 (8.1)	4.1 (0.9)
Analyze the advantages and disadvantages of a potential intervention	Debate Papers	86.3 (5.7)	4.1 (0.9)
SELECTED BASIC LEARNING OUTCOMES			
Explain the basic principles of epidemiology, including rates, risk factors, disease determinants, causation and public health surveillance.	Quiz	80.8(12.2)	4.1 (0.9)
Explain the impact of communicable and chronic diseases on the health of a population and approaches to prevention and early detection.	Quiz	80.2 (11.8)	4.3 (0.8)
Describe the basic organization of health care and public health systems	Quiz	81.6 (10.8)	4.2 (0.8)
All 13 Basic Learning Goals	All Quizzes	79.7 (7.4)	

first undergraduate survey course, adopted from Riegelman and Albertine (2008), directed toward the knowledge level of Bloom's taxonomy. See Table 1 for examples. For instance, to research and evaluate literature supporting or opposing mandatory HPV vaccination for debates, students must understand basic principles of epidemiology and impact of communicable disease.

Course Activities

During the term, six debates were held with students offering positions on different sides of important timely public health issues (Table 2). For each topic, all students were required to compose a position paper, taking a side on the proposition and researching and supporting their position with acceptable scientific references. Four students, in teams of two, presented their arguments for and against the proposition, and were scored by the class. These debates thus required students to take responsibility for their own learning, mastering basic public health concepts through text reading and their own research, in order to address the issue effectively. Debate papers were assessed by the instructor using a scoring rubric provided to students. (Appendix 1).

TABLE 2. Issues Debate Topics

Issues Debate Topics
Communicable Disease: Should HPV Vaccination be Required?
Communicable Disease: Should H1N1Vaccination be Required?
MDR Tuberculosis Control Through Mandatory Treatment
Obesity and Soda Tax
Obesity and Restaurant Calorie Count Posting
Obesity: Lifestyle Modification vs Drug Treatment
Access to Health Care: Should Minute Clinics be Licensed in Drug Stores?
Approaches for Reducing Emergency Department Overuse
Approaches for Reducing Infant Mortality
Health Care Politics and Finance: Massachusetts Health Insurance Reform Law Pro and Con
National Health Care Reform: PPACA Pro and Con
Mental Health: What to Do with Returning Iraq Veterans with PTSD?
Health Related Behavior, Prevention: Tobacco Sales Restrictions
Tobacco Use Reduction on College Campuses
Racial and Economic Disparities in Health and Health Care

Several videos highlighting public health topics were shown and used as the basis for reflection papers and class discussion. These included Unnatural Causes: How Inequality is Making Us Sick (California Newsreel, 2008), Typhoid Mary (PBS: Nova, 2004), Influenza 1918 (PBS: American Experience, 1998).

The text (McKenzie, Pinger and Kotecki, 2008) was used to provide case studies for frequent classroom and small group work and discussion, in about one third of classes. A small portion of the course, approximately one fifth of class meetings, included instructor lectures, briefly reviewing major concepts. There were some short homework assignments; for example, students were required to analyze, compare and contrast short internet commercial videos on the HPV Gardasil vaccine or on internet media commentary on H1N1 influenza. Guest lectures invited speakers on the politics of Massachusetts and national health care reform, influenza preparedness procedures for the H1N1 epidemic at a large group medical practice and public health issues in Haiti, as seen in a rural health organization.

Two-three single class discovery activities using technology/internet were conducted, with students working in teams. A personal health insurance research activity used the Massachusetts Commonwealth Health Insurance Connector to attempt to find a plan affordable for a college graduate without employer coverage; an analysis of health outcome disparities compared surrounding communities with different socioeconomic profiles; a chain of infection profile was constructed for currently active threats such as West Nile virus.

The class met for three fifty-minute periods per week and additionally required twelve to fifteen hours of direct involvement in health-related service in the community. Students were required to maintain a reflective Service Learning Folio, guided by a formal scoring rubric provided in the syllabus (Appendix 2). These were collected at mid-term and the end of the course and graded using the rubric provided.

Students had several options for connecting with a service activity, facilitated by the Merrimack College Stevens Service Learning Center. Their major program is the Lawrence Math-Science Partnership (LMSP), in which college mentors conduct weekly health-focused after school constructivist discovery STEM learning activities (Table 3) with middle school students in community after-school programs in Lawrence, MA. Lawrence is an economically disadvantaged community, near the bottom of state rankings for mean family income, with a majority Latino population (90% in the public schools), high rates of poverty (85% of students qualify for school meal assistance) and 20% of public school students with English as their second language. (Foote and DeFillipo, 2009).

TABLE 3. Sample Lawrence Math-Science Partnership Learning Activity Topics

Sample Lawrence Math-Science Partnership Learning Activity Topics
Diet and Wellness: Vitamin C Indicator Test
Food Safety: Cooking Right to Eat Right (hand washing demo)
Nutrition: Understanding Nutritional Information
Oral Health: Healthy Habits
Infectious Disease: Saving the World from Illness
Lung Capacity, Exercise and Smoking
Cells and Body Chemistry: The Brain
Exercise Physiology: Heart Rate and Fitness
Microbes and Immunity
The Power of Food
Nutrition: That's What I've Been Eating!
Heart Disease (Atherosclerosis)
Melanoma

The Stevens Center also provides health-focused placements in other community agencies, such as Marland Place Senior Living, American Red Cross, etc. Students may find service learning placements individually, volunteering for example, in an Alzheimer unit in a local nursing home or participating in events such as organizing a blood drive. Overall seventy of 192 students (36%) participated in the Math-Science Partnership; thirty-six of 192 (19%) in other placements arranged by the Stevens Center and eighty-six of 192 (45%) in sites and activities selected and arranged by students on their own initiative.

Assessment

Performance Assessment

The course grade was based on six quizzes on chapter readings and lectures (30%), debate performance and papers (20%-Appendix 1), service learning folio (20%-Appendix 2), homework writing assignments (15%), class discussion (10%-2010 only), SALG survey (5%).

Perceptual Assessment

For 5% of their grade, students were given instructions and due dates, during the week prior to the final exam, to complete the Student Assessment of Learning Gains (SALG; http://www.salgsite.net; Seymour et al., 2000), a web-based instrument developed for assessing the effectiveness of college level science courses. This instrument has been adopted by SENCER and includes many items relating to civic engagement. It assesses student perceptions of the degree to which various course aspects improved their learning. The instructor modified the standard SALG template to add additional numerical questions pertaining to the specific learning goals and activities of this course, and text box questions for narrative responses. After submission of final course grades, the survey data were downloaded for analysis. The SALG site allows the instructor to pool results from different years for analysis, of both numerical response items and narratives, which can be coded for content analysis. The instructor can track which students responded, but cannot link that information with the specific responses.

Results

Performance Assessment

The performance assessments are mapped to the three advanced goals and to quiz results for selected basic learning goals in Table 1. These basic goals were represented as examples since they mapped directly to single quizzes. Grades from all three years of the course for 192 students were pooled. On the three most highly weighted assessments, students averaged 86.3 mean (5.7 standard deviation) on debates, 79.7(7.4) on all six quizzes and 92.1(6.5) on the service learning folios. Quiz results were slightly lower and more variable across the population than the other assignments.

Perceptual Assessment

Table 4 summarizes the numerical results for SALG items most closely related to civic engagement. Table 5 summarizes a content analysis of the themes appearing in narrative text box responses. Table 6 shows sample quotes from the SALG narratives.

Real World Issues

More than 70% of students reported that the focus on real world issues and science-civic issue interplay were of much to great help in their learning. In narratives on civic and political integration, greater attention to politics, involvement in service learning and single event participation were most often mentioned. In the class activities section, the items most directly related to civic issues (debates, videos and case study class discussions) were most highly rated; 75% of students

TABLE 4. SALG Results

5=great help/gain: 4=much help/good gain; 3=moderate help/gain			
The Class Overall			
HOW MUCH did the following aspects of the class help your learning?	**Mean(sd)**	**Mode**	**%4,5**
Addressing real-world issues	4.3(0.89)	5	80
Interplay between science and civic issues	4.0(0.86)	4	71
Class Activities			
HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	**Mean(sd)**	**Mode**	**%4,5**
Presentations/lectures from course instructor	4.0(0.99)	5	68
Discussions in class	4.1(0.91)	5	77
Group work in class	3.8(1.07)	4	63
Computer-based work	3.3(1.11)	4	46
Media such as videos, film or slides	4.3(0.85)	5	80
Debates in Class	4.1(1.08)	5	75
Presentations by guests	3.7(1.07)	4	60
Required service learning activities	3.5(1.19)	4	53
Increases in your skills			
As a result of your work in this class, what gains did you make in the following skills?	**Mean(sd)**	**Mode**	**%4,5**
Apply scientific information to social concerns	3.9(0.99)	4	70
* Analyze public health problem, cause, intervention, implementation	4.2(0.90)	5	78
* Evaluate public health information in media, Internet	4.1(0.91)	5	75
* Analyze advantages and disadvantages of public health intervention	4.1(0.89)	4	78
Class impact on your attitudes			
As a result of your work in this class, what gains did you make in the following?	**Mean(sd)**	**Mode**	**%4,5**
Interest in reading about science and its relation to civic issues	3.7(1.03)	4	59
Interest in exploring career opportunities in science	4.1(1.06)	5	72
Interest in attending graduate school in a science-related field	4.0(1.15)	5	69
Interest in teaching science	2.8(1.36)	4	35
Interest in volunteering for science-related community service	3.6(1.23)	4	58
Interest in participating in non-formal science education at a museum or a school	3.1(1.26)	3,4	42
Integration of your learning			
As a result of your work in this class, what gains did you make in integrating the following?	**Mean(sd)**	**Mode**	**%4,5**
Writing a letter or email a public official about a civic or political issue	3.1(1.25)	4	39
Debating or offering public comment on a scientific issue	3.5(1.12)	4	55
Debating or offering public comment on a civic or political issue	3.4(1.17)	4	50
Attending a meeting, rally, or protest about a civic or political issue	3.1(1.20)	4	38
Writing a letter to the editor about a civic or political issue	3.0(1.31)	4	35
Participating in science-related civic education	3.2(1.23)	3	42
Doing an internship at a civic organization	3.2(1.23)	3,4	42
Participating in one-time civic events such as walk-a-thons	3.6(1.18)	4	53
Voting in elections	3.9(1.19)	5	64

TABLE 5. Narrative Content Analysis

Civic, Politcal Integration of Learning?	
N=104	%
Attention to Politics	15
Service Learning	12
Single Event Participation	4
What course activity helped you learn the most?	
N=161	**%**
Debates	46
Videos	27
Group Work	9
Service Learning	8
Class Discussion	6
Changes in Understanding?	
N=152	**%**
Awareness of PH Issues	29
Scope of PH	18
Socioeconomic Status	12
Finance of PH	7
Epidemiology	5
Increased Interest?	
N=120	**%**
Further Study in PH	16
Clinical Practice	6
Teaching	5
Skills Gained?	
N=120	**%**
Presentation	15
Information Gathering	7
Issue Analysis	6
Suggested Changes?	
N=153	**%**
Grading Scheme	12
No Change	11
More Videos	7

reported that these were of much to great help. When asked what class activity helped them learn the most, students identified issue debates, videos, group work, service learning and class discussion most frequently. In narrative responses on assessing changes in their understanding, increased awareness of important current public health issues, of the scope of public health, of socioeconomic status effects on public health, of finance and funding and of principles of epidemiology were most commonly mentioned. Respondents indicated increased interest in further study in public health, clinical practice and teaching science.

Skills Gains

In skills gains, the three starred items in Table 4 are the advanced course learning goals. Over 75% reported good to great gains in these skills, with 70% reporting good to great gain in applying scientific information to social concerns. When asked which skills they had gained, most frequently mentioned were oral presentations (debates), research information gathering and evaluation and ability to analyze issues using the public health framework (Table 5).

Basic Knowledge Gains

There were thirteen basic learning objectives focused on content knowledge as presented in the text and assessed by quizzes. On all these items, students indicated that they felt that they had made good to great gains in their understanding (means 4.0 to 4.3, all modes of 4 and 5). These perceptions compare with an overall quiz average of 79.7(7.4). Selected specific basic learning goals are reported in Table 1.

Impact on Attitudes and Integration of Learning

The six attitude impact items related to future interests were somewhat lower rated, with means in the moderate to good range (means of 2.8-4.1) and 35-72% reporting good or great gains (4 and 5). Interest in volunteering for science related community service (3.6, 58% good to great gains) was most relevant to the course goals. As expected in a majors class, career opportunities in science (72%) and intention to attend graduate school (69%) were the most highly rated; interest in teaching science was the lowest rated (35%), but in the narrative responses, several comments indicated enthusiasm about teaching science. The responses to this category of attitudes showed greater variability than previous categories, as seen in response distribution. Items relating to activities of civic participation also fell in the moderate to good range, with voting in elections the most highly rated in this category, 3.9 mean and 64% indicating good to great gains.

TABLE 6. SALG Sample Student Comments

What course activity helped you learn the most? Describe why it helped you learn.
"The debates were probably most helpful to my learning because the debates focused on real life issues that were happening today.
"I believe the Debate activities was a place where I learned the most due to having to research information of both positives and negatives and support arguments with evidence. This helped us think critically as well as covered presentation skills.
"I think watching the videos helped the most because you can read about each problem in many ways but once a face is attached to the problem it seems more real"
"The videos were a great help and eye openers. They showed real stories and actually let me see just how people are affected by many different aspects of their lives. Applying the course material to the real-life scenarios in the film was helpful and interesting."
"The service learning helped me the most because it helped me relate in class discussions to real world topics.
"I thought the service learning was a crucial part of the course. I was able to apply the skills we learned about in class and make a difference!"
"the required service learning activity then writing about it our folios because the material from the text and in class we applied to our own experiences/interests."
Please comment on how your understanding of the subject has changed as a result of this class.
"I learned a lot in this class, especially about the various health issues that are largely prevalent in societies today. The number of efforts that are being placed to resolve health issues has encouraged me to get more involved in prevention and health promotion activities."
"I now realize that fixing health problems in a community are not as easy as I once thought. There are several factors, such as cost, feasibility, and the population that need to be taken into account. I now better understand the process of intervention and implementation. "
"I did not have any idea about so many current events that were occurring in our country today. I loved being able to relate current events to my field of study. "
As a result of this course, has your interest grown in any other activities related to science?
"I have always loved science but public health has helped to put all the pieces of science together."
"I have become more interested in the community aspect of health as opposed to the individual aspect. "
"My interest in wanting to work with children or teaching science in the future has increased after being a member of the Lawrence math and science partnership for the civic engagement for this course. "
"I am excited to work towards becoming a Health Teacher"
"I have become more interested in volunteering from this course"
"community service with public health issues"
Are there other ways you have integrated your learning in this class to a civic or political area?
"Yes...I submitted a response in a scientific medical journal that asked about ways to solve the current crisis in primary care...I used the research done in this class to writet a response to the forum..."
"Writing the letter about banning selling cigarettes integrated the subject of civic and political issues into class."
"Discussing the problems w/ fam. and grandparents and getting real life application. "
"It has made more attentive to what our officials are doing in Washington, therefore has increased my interest in local and state politics, and not just the federal level. "
"The main way that I integrated my learning is by gaining interest in participating in a one time civic event."
"Going into the city of Lawrence each week for the Math and Science Partnership was a great way to integrate things that I was learning about. "
"When volunteering at Bellesini Academy I used most of the information obtained in class and taught them a little useful information."
"This class has allowed me to better my conversation skills pertaining to political conversations. "
"Taking part in the health field promoting fitness and nutrition."
"The class, with the help of the debates, allowed me to focus more on the issues that surround us as a community."
"become more involved in community activities"
"During this election, I took note of the candidate's take on health insurance and care"

Service Learning Impact

The service learning activities were rated of moderate to much help in learning by 53% (mean 3.5). The service learning folios completed by students also offer comments on the value of this aspect of the course. These folio entries are often surprising in the depth of the reflection and the awareness of the value of this kind of civic engagement both for themselves as learners and for the populations with whom they are working. Uniformly, the reflections describe an increase in awareness of, for example, the striking differences between the city of Lawrence and the upper middle class communities of Andover and North Andover where the college is located, or the real challenges faced by elders dealing with failing physical health and dementia. The theme of making a difference appears frequently.

> "Overall, I think it was an awesome way to end my LMSP because I left there feeling that I really showed the girls how they personally could make a difference in a world that seems so big and scary. It only takes one person's help and one person's support to start the ball rolling and these girls were able to realize that…."

> "I learned a lot from these kids every day, as well as them learning from us, and I believe that they were able to benefit a lot from our presence. Overall, I believe that this program is very important to public health because it promotes the idea of education and college to these young, inner city kids who are anxious to learn, and are looking for people to teach them."

> "This week's class topic on alcohol, tobacco and other drugs relates to my experience at Adelante …. The kids that I work alongside every week face many, if not all, of the risk factors that contribute to the probability of substance and drug abuse. …My experience … helps to promote educational awareness about many health problems, in order to protect from bad choices due to lack of understanding and giving in to pressures."

Course Changes

In terms of one possible course improvement (Table 5), changes in the grading scheme, particularly quizzes (12%), no suggested changes (11%), and more videos (7%) were the most prevalent comments. The quizzes were designed to insure that students were reading and mastering the basic content learning objectives. Responses cited a wish for fewer quizzes, easier quizzes, including debate subjects in the quizzes, help in quiz preparation, etc.

Discussion

The hypothesis of this study was that an emphasis on current challenging public health issues and a service learning experience would generate positive attitudes toward and engagement with civic issues, while achieving the course learning goals using active learning techniques. The results of the perceptual SALG survey and student performance on assessments support the hypothesis.

Impact of Real World Civic Issues Focus

Several national science organizations, in setting goals for the pedagogy of the future, have emphasized experiential learning and direct engagement with the scientific issues facing society. Project Kaleidoscope, for example, foresees "an environment in which learning is active, investigative and experiential, where the curriculum connects to the world beyond the campus…" (PKAL, 2002, p. 5). The National Research Council (Bransford, et al., 1999) also suggests that real world problems can be of great value for learning in the science classroom. The NSF SENCER initiative expressly aims to teach to science through complex unresolved civic issues (SENCER, 2011).

Public health affords an excellent opportunity to incorporate these aims; it is highly interdisciplinary and has the explicit applied goal of health promotion and disease prevention. We are faced with many difficult issues, such as emerging and reemerging infectious diseases and threats to health from the chronic lifestyle-related obesity and diabetes epidemics. Sadly, on several accepted measures of population health, such as infant and maternal mortality and life expectancy, the United States ranks quite poorly in comparison with other industrialized countries. The goal of undergraduate public health education is 1) "to produce an educated citizenry who can be expected to examine the evidence and to evaluate critically public health goals and methods. An educated citizenry can also be expected to make political and financial commitments to support successful public health interventions." (Riegelman et al., 2007, p. 4). Even students who do not pursue public health as a career will vote on issues affecting public health in elections. Many citizens may become involved in health related community and school based-programs.

To introduce a focus on complex unresolved civic issues, it is only necessary to read the news regularly. This course focused first on a specific issue and used that issue as a lens for students to examine and learn the public health principles. The SALG data showed that students strongly supported the issue-focused debates as an effective learning tool. The topics were drawn from the latest headlines and were often chosen to be of direct relevance to the college population. For example, to evaluate the question of cervical cancer vaccination, students had to grapple with basic principles of communicable disease transmission, vaccine development and implementation, descriptive statistics on disease frequency, questions of effectiveness, risk, cost and access, etc. Each of the debate issues in turn required students to research and master various aspects of public health.

The information derived from the SALG survey of this course can be compared to data from an evaluation of SENCER courses based on over 10,000 student SALG evaluations (Weston et al., 2006). SALG scores in this course exceeded levels reported in the overall evaluation. For example, students rated focus on real world issues as 4.3 here vs 3.61 and interplay between science and civic issues 4.0 vs 3.45. This trend is also evident on civic engagement items, with scores for this course higher, means of 3 and above, than the overall evaluation, with means of 2 and above.

Students also responded very positively to the issues focused videos. The Unnatural Causes series particularly resonated strongly with students in its depiction of real people facing real problems. As class debates focused on state and national health care reform and the Affordable Care Act was working through Congress, students were able to see, in a video segment, the effect that moving a manufacturing plant from Michigan to Mexico had on the health of the community resulting from job and health insurance loss, as well as a comparison to the effect of and different response to a similar plant relocation from Sweden to eastern Europe. This gave a face to the topics of health care finance and policy.

Impact of Service Learning

The experiential component of the class was the required service learning experience, designed to get students out in the community to directly experience the challenges to population health around them. Available literature, as summarized by Eyler et al., (2001), in an extensive review of hundreds of studies, indicate that service learning has a positive effect on citizenship skills and social responsibility (twenty-three papers) and on commitment to service (twenty-six papers). Astin and Sax (1998) studied 3450 students at forty-two institutions and report that involvement in service learning at the undergraduate level enhances sense of civic responsibility. Astin, Sax and Avalos (1999) surveyed 12,376 undergraduate and high school service-learning participants nine years after college entry and found enhanced likelihood of engagement in volunteer community service work after college. Foote and DiFilippo (2009) also indicate that service learning participation enhances engagement with the outside community, increases student awareness of community issues and enhances exposure to diversity of race and culture, with service learning participants displaying a greater commitment to community service later in life. The overall SENCER SALG evaluation also indicated that courses with service learning may facilitate future involvement in service (Weston et al., 2006).

Our campus has a very active service learning center, supported by the College mission of valuing community service and engagement. The LMSP, in which more than a third of these students participated, has been evaluated in detail (Foote and DiFilippo, 2009). Over a three-year period, 97% of 207 survey respondents (of 434 participants in the program) noted that this program had contributed a lot to their development in the area of contribution to society. Many of the narrative comments in the SALG survey here support this finding. In the fall, the LMSP activities conducted with the middle school youth almost all relate to health topics. Thus, while debating programs to curb the obesity epidemic in class, the college mentors were working on nutrition and movement related activities with the youth. At the same time, their journals often noted student behavior and casual conversation around food issues that illuminated the multidimensional nature of the problem. For example, young students remarked that they ate at fast food restaurants many times per week, because parents held multiple jobs, had no time to cook and limited access to fresh foods at reasonable prices, a situation they had also seen in a video segment. Students working in settings other than LMSP were able to make similar connections between their work and class issues. A majority of the students considered the service-learning component to be of good to great value to their learning, though it was not as highly rated as the debates and videos. It should be noted that the service learning did require that time be scheduled outside class, both at the site, to travel to it (transportation to LMSP sites is provided) and to write the reflective journal. As students get busier as the term progresses, this may become more difficult. A small number of complaints about these issues did appear.

The question remains as to whether this course will affect future civic engagement by these students, a finding described by Sax et al. (1999). An examination of the SALG items relating to attitude impact and integration of learning showed moderate gains from the course in areas such as attending a meeting regarding a civic issue, participating in civic education, etc. Interestingly, the highest rated items in this area were participation in one-time events, such as fundraisers, and voting in elections. The ratings for these items exceeded those for the global SENCER SALG assessment. (Weston et al., 2006). It may be that as first term sophomores, these students remain focused on college concerns and events they can do easily that do not require sustained commitment or off campus involvement.

Impact of Active Learning Pedagogy

This course used primarily active learning methods and students responded quite positively to activities such as debates and class discussions, which placed responsibility for learning on their engagement with the material. Combining these methods with an issues focus, rather than simply lecturing on the issues, enhanced student learning.

Challenges and Limitations

It was interesting that although quizzes made up only 30% of their course grade, compared with 100% in many courses, students tended to focus a great deal on their quiz grades. Since assessment in science courses is often highly focused in high stakes tests, this is not unexpected. The remaining 70% of the course grade was based on writing assignments, yet students needed to be encouraged to invest as much effort on those as on test preparation. Given the large number of writing assignments, this model of the course is a challenge to instructors. Since sections were large, with the instructor handling two each term, commenting at length on student writing and returning papers quickly for feedback is often difficult. The biggest issue encountered in these papers was difficulty with identifying and using reputable scientific sources and citing them appropriately, rather than using the first five hits off a Google search. Despite materials provided on information literacy, this remains a problem and more specific guidelines for sources and a class with a reference librarian would be helpful. Large class sizes can also inhibit discussion. Recently a grade for participation was added, with mechanisms for tracking contributors. The idea of having every student prepare a position paper on every debate issue attempts to insure that everyone has background information to add to the class; inducing students to speak up is still a challenge. There was much positive response to small group discussions, where comfort level with three or four peers is greater. Another challenge is that of bringing the service learning experience into the classroom, so students can share experiences and connections to the issues. While the instructor has the privilege of reading the reflective journals, others are not benefitting and some classes devoted to journal-based discussion should be helpful.

In summary, students responded very positively to an undergraduate course in public health designed to teach basic principles through complex challenging civic issues, while connecting to those issues directly through service in communities.

About the Author

Kathleen A. FitzPatrick, Ph.D. is Associate Professor of Health Sciences and has taught a variety of courses in health related areas for many years at Merrimack College. She received her bachelor's degree in biology-chemistry from Lawrence University in Appleton, WI and the Ph.D. in physiology from the University of Wisconsin at Madison. She has attended two SENCER Summer Institutes as well as local SENCER events and attempts to incorporate these principles in her courses and she has a strong interest in implementing various methods of active and engaged learning in her classes.

References

Association of American Colleges and Universities. 2007. College Learning for the New Global Century. A Report from the National Leadership Council for Liberal Education and America's Promise, Washington DC. www.aacu.org/leap/documents/GlobalCentury_final.pdf. Accessed May, 2011.

Astin A.W. and L.J. Sax. 1998. How Undergraduates Are Affected by Service Participation. Journal of College Student Development 39:251-263.

Astin, A.W., L.J. Sax and J. Avalos. 1999. Long Term Effects of Volunteerism During the Undergraduate Years. The Review of Higher Education 22.2:187-202.

Bransford J.D., A. Brown, R.R. Cocking, eds. 1999. How People Learn: Brain, Mind, Experience, and School. Washington, DC: The National Academies Press.

California Newsreel. Unnatural Causes: Is Inequality Making Us Sick? 2008. A seven part video documentary series exploring racial and socioeconomic inequalities in health. San Francisco, CA.

Eyler J.S., D.E. Giles, C.M. Stenson, C.J. Gray. 2001. At A Glance: What We Know about the Effects of Service-Learning on College Students, Faculty, Institutions and Communities, 1993-2000. Third Ed. Washington, DC: Corporation for National Service. www.compact.org/wp-content/uploads/resouces/…/aag.pdf. Accessed November, 2011.

FitzPatrick K.A. 2009. "Community Based Service Learning in an Issues Focused Public Health Class". Paper presented at the Science Education for New Civic Engagements and Responsibilities (SENCER) Summer Institute, Chicago, IL. August 8.

Foote L.C. and J.E. DiFilippo. 2009. "STEM Literacy, Civic Responsibility and Future Vision: Examining the Effects of the Lawrence Math and Science Partnership". In Partnerships for Service Learning: Impacts on Communities and Students. Kelshaw T.F. Lazarus, J. Minier, eds., 165-205. Hoboken, NJ: Jossey-Bass/John Wiley and Sons, Inc.

McKenzie J.F., R.R. Pinger and J.E. Kotecki. 2008. An Introduction to Community Health. Sudbury, MA: Jones and Bartlett Publishers.

Project Kaleidoscope. 2002. Recommendations for Action in Support of Undergraduate Science, Technology, Engineering and Mathematics. Report on Reports. Washington, DC. http://www.pkal.org/documents/ReportOnReports.cfm. Accessed May, 2011.

Public Broadcasting Service. Typhoid Mary (Nova, 2004. Nancy Porter Productions, Inc. and WGBH Educational Foundation.); Influenza 1918 (American Experience, 1998). Arlington, VA.

Riegelman, R.K., S. Albertine, N.A. Persily. 2007. The Educated Citizen and Public Health: A Consensus Report on Public Health and Undergraduate Education. Council of Colleges of Arts and Sciences. Williamsburg, VA. http://www.ccas.net/i4a/pages/index.cfm?pageid=3351. Accessed, May, 2011.

Riegelman, R.K. and S. Albertine. 2008. Recommendations for Undergraduate Public Health Education. Association of American Colleges and Universities. http://www.ccas.net/i4a/pages/index.cfm?pageid=3351. Accessed April, 2011.

Science Education for New Civic Engagements and Responsibilities. http://www.sencer.net/About/projectoverview.cfm. Accessed May, 2011.

Seymour E., D.J. Wiese, A.-B. Hunter, S. Daffinrud. 2000. "Creating a Better Mousetrap: On-line Student Assessment of Their Learning Gains". Paper presented at the National Meetings of American Chemical Society Symposium: "Using Real-World Questions to Promote Active Learning". San Francisco, CA.

Student Assessment of Learning Gains (SALG). http://www.salgsite.org

Tewksbury, B.J. and R.H. MacDonald. 2005. Cutting edge course design tutorial. http://serc.carleton.edu/NAGTWorkshops/coursedesign/tutorial/. Accessed April, 2011.

Weston, T., E. Seymour, H. Thiry. 2006. Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project. Prepared for the National Center for Science and Civic Engagement. http://www.sencer.net/Assessment/independentevaluation.cfm. Accessed Nov. 25, 2011.

APPENDIX I Issue Debate Paper Evaluation and Grading Criteria

Entries must be word-processed. Each debate position paper is worth 10 points.

1. Paper has a specific title and position on issue is clearly stated in first sentence.	
2. Organization and Clarity	
HIGH A	a. Position on issue is stated in an organized and clear manner b. Position on issue is supported by legitimate evidence c. Position is presented in objective terms, without editorializing d. Structure of argument and evidence effectively persuade reader of validity of your position
B	a. Position is unclear or muddled and not persuasive due to lack of good evidence b. Unsupported points and /or personal opinion are used to argue position
Low C	a. Assignment appears to be treated casually, with little care given to constructing a cogent argument b.Argument includes inappropriate prejudices, bias
3. Evidence	
HIGH A	a. 3-5 annotated references used to support argument, not to include starter references provided in assignment b. All References are legitimate scientific sources and directly relevant to position c. At least 1-2 references are primary research article sources d. References are cited in the text body (Smith, 2009) at points where ideas derived from them are presented e. References are listed in alpha order by author at end of text, using CSE format f. Website references from .gov such as the CDC, .edu such as a university, only g. Direct quotes are indicated as such " " and source clearly identified.
B	a. References provided but derived from inappropriate sources (commercial websites, commercial news outlets, popular media, personal websites and blogs) b. References cited section provided, but in text references not provided c. References cited section in incorrect format or not annotated d. Words of others not set off in quotes and referenced
Low C	a. Provides no references
4. Writing Quality	
HIGH A	a. Work is completely free of grammar, spelling, punctuation, or readability problems
B	a. Work contains errors (incomplete sentences, words missed by spell-checkers, etc.) that should have been caught by proofreading b. Writing is too casual and distracts from the content.
LOW C	a. Work is replete with careless errors and/or serious English writing problems in grammar, spelling, punctuation, and readability b. Lacks coherence

The **Experiential Learning Folio** is a tool for guiding reflection, for developing skills and understanding and for fostering self-knowledge. This journal has a special format designed to assist you in your reflections on the readings, our classes, and your experiences in order to clarify the connections between the three. I expect you to make an entry for each service visit (you will have between 5 and 10 entries, depending on the number and length of your service visits). *(Adapted from Dr. Gina Vega, Dept. of Management).*

Format

- Set up your Learning Folio in three sections (Reading, Experience, and Reflection) and date each new entry that you make.
- **Reading** is where you will write about something that held your attention in one of the class readings. Maybe it made you angry, maybe it made you sad, or it made you think, or you connected to it in some other way. Maybe it just confused you. Or maybe it related to a question posed that week in class. Whatever your strongest response was, that is the one to write about.
- **Experience** is where you will write about something that happened to you in the course of your learning activity. Maybe it was a conversation with someone at your site, maybe it was something you overheard or saw, maybe it had to do with the service itself. Or maybe it related to assigned reflection questions to look for in the service process. Whatever incident made an impact on you, that is what you will write about.
- **Reflection** is where you will connect the reading and your experience. Sometimes this will be difficult. Nonetheless, I urge you to try diligently to make the connection with your experience. The end goal of this section is to make you think about what you have been doing, ask yourself why your experiential work is needed, and what you should do about it now and in the future. In this section, you should explicitly identify how the experience relates to the three 3 Ps of public health (Promote, Protect, Prevent) and to the 4 step approach to population health (Problem, Cause, Intervention, Implementation). The entry for each date should be one or two pages. Save the entry on a disk and back it up somewhere. The folio for the first half of the semester is due at midterm on October 21 and the second half is due on December 2.

APPENDIX III Experiential Learning Folio Evaluation and Grading Criteria

Entries must be word-processed. Each entry is worth 10 points.

1-Entry identifies the service site or agency, date of activity and total time spent.	
2. Selection of Experience	
HIGH 3	• Description of event is clear and comprehensive; • Description indicates care in the selection of the event • Description presents the event in objective terms, without editorializing
2	• Description of the event is unclear or muddled • Reflection or opinion is included in this section
Low 1	• Assignment appears to be treated casually, with little care given to selecting a meaningful experience • Choice of event is insignificant
3. Quality of Reflection	
HIGH 3	• Indicates careful and thoughtful consideration of the purpose of the service • Identifies the specific learning that results from the service • Shares the personal impact of the service with the reader • Suggests actions that can be taken to assist the people being served • Makes the thought process transparent (i.e., obvious to the reader) • Makes a clear connection between readings and experience
2	• Lacks an action plan or recommendations • Makes multiple mutually inconsistent or contradictory statements • Does not make the link between service and learning
Low 1	• Provides little to no analysis of the mutual impact of service • Provides little or no evaluation of the service learning • Provides little or no evidence of critical thinking based on the service
4. Writing Quality	
HIGH 3	• Work is completely free of grammar, spelling, punctuation, or readability problems
2	• Work contains errors (incomplete sentences, words missed by spell-checkers, etc.) that should have been caught by proofreading • Writing is too casual and distracts from the content.
LOW 1	• Work is replete with careless errors and/or serious English writing problems in grammar, spelling, punctuation, and readability • Lacks coherence

PROJECT REPORT

Incorporating Quantitative Reasoning and Civic Engagement in a College Algebra Course Through A Lesson on Interest Rates, Debt and Student Loan

Reem Jaafar
Department of Mathematics, Engineering and Computer Science
LaGuardia Community College, C.U.N.Y.

Concerns about adequate education in Mathematics and the Sciences have pushed many researchers in the field of Education to appreciate quantitative literacy. Quantitative literacy or numeracy is the analogue of the ability to read and write but in quantitative data and numbers. As Lynn Steen (Steen 2001, 2) mentions in *Mathematics and Democracy*, it is looking at this world "through mathematical eyes."

Although the idea of quantitative literacy dates back to a British government report in the 1950s (Fowler 2003), renewed interest in the subject was not revived until the late 1990s (Paulos, 2001). Quantitative literacy is viewed as a "critical skill for economic success" (Root, 2009) especially in a highly competitive job market. Quantitative literacy should be viewed as a skill that should be implemented across the curriculum. At schools it should be an integral part of the curriculum. At a two-year college, it is very important for students to acquire the necessary quantitative literacy skills in order for them to succeed and eventually transfer to the four-year college.

Quantitative literacy, unlike mathematics in general, is inseparable from its context. It inherits its content from its context (Steen 2001, 17). So it is best to teach quantitative literacy by looking at a context that is relevant to students' lives. The SENCER project (Science Education for New Civic Engagements and Responsibilities), engages students in relevant civic issues while teaching mathematics and science content. In that regard, quantitative literacy and civic engagement can give students an adequate education. In fact, some authors (Root, 2009) suggest implementing quantitative literacy across the curriculum to tackle the broader issue of social justice.

Various books have also been written about the subject (Steen 1997, 2001, 2004). In them, the author makes a case for the universality of quantitative literacy by detailing the importance of quantitative skills in various academic fields, profession and everyday life. In the latter case, he details the importance of quantitative reasoning in every major public issue such as: how to interpret data presented in voter information pamphlets, understand how different voting procedures can influence the results of an election, understand size of numbers and orders of magnitudes, analyze demographic data, understand the difference between rates and changes in rates.

According to Steen (Steen 2001, 8), quantitative literacy has several elements: the confidence in using quantitative methods, the appreciation of the role of mathematics in science and culture, the ability to understand and interpret data, the use of logical thinking in making decisions, the ability to use mathematics in a given context, the ability to estimate numbers accurately, and the transfer of skills to apply mathematical knowledge to real-world problems. These features will be incorporated in our projects by having students learn about debt, interest rates, and the effect of debt on their lives. The project will also try to enhance students' communication skills by having them give real-life advice using what they have learned. It is important to note that quantitative reasoning is implemented in several colleges as an integral part of all of the subjects, and there is an advocacy to make it an "across-the-curriculum approach" in order to provide a variety of opportunities for practice (Steen 2004, 17).

While some view quantitative literacy and quantitative reasoning as synonyms, others differ in how these terms are applied. George Cobb, a statistician, views quantitative reasoning as an "interpretative activity that takes place within a deductively structured framework" (Steen 1997).

According to Cobb, the term "quantitative literacy" tempts us to think that it is about whether one can count or calculate, whereas, quantitative reasoning requires a difficult integration of four different kinds of thinking: computational/algorithmic, logical/deductive, visual/dynamics and verbal/interpretative.

Most of the definitions, however, agree that quantitative literacy or reasoning centers around applying mathematical concepts to real-life problem solving. Throughout the rest of this paper, the expression "quantitative reasoning" will be used when referring to the project described since students were using it in an interpretative activity and were engaged in the four kinds of thinking defined by Cobb.

The SENCER Model and Learning Goals

In recent years, there has been a great effort to implement the SENCER model across the curriculum (http://myweb.lmu.edu/tzachari/SENCER.html, accessed November 8, 2011). In particular, Zachariah, Larson and Dewar designed a course on "quantitative literacy through community- based group projects." The aim of the course was to enable students to connect and apply their classroom learning to their own lives and community while emphasizing "active citizenship." They suggest several topics relevant to students, including credit cards, savings, taxes, investments, and student loan debt. Their project will be described at a later stage in the paper. My project adopts the SENCER Model in introductory college algebra and was assigned to students at LaGuardia Community College in Long Island City, Queens as part of the Project Quantum Leap. Project Quantum Leap (PQL) implements the SENCER model in developmental and introductory math classes in order to enhance student-learning outcomes using topics in health, environmental science and finance. In this paper, the topic presented is related to finance. The project will help students enhance their quantitative reasoning skills while exposing them to issues that are relevant to them.

It is appropriate to implement SENCER-based projects in college algebra since the course is viewed as central in any mathematics curriculum, and as the boundary between high school and college (Steen 2004, 38). Implementing it using the projects described below will help students master quantitative reasoning and critical thinking skills without a major alteration in the course syllabus.

There are several learning goals for this project. First, the project aims to help students overcome the "formula anxiety" when faced with certain mathematical problems and to use their senses to estimate payments, rather than solely rely on recipes they usually learn and forget shortly after.

Rigorous mathematical background is essential, but in introductory algebra, it is important for students to learn how to reason and argue using numbers. Second, the project aims at helping students understand the difference between interest and principal, the effect of the interest rate on monthly payments and determine the accumulative effect of interest and the consequences of debt accumulation. Other goals include: to understand the amortization table, to learn about the problems with the deferral student loan system, to be able to develop skills to estimate monthly payments on loans, to understand the bureaucracy behind students loans and engage in reflective writing on how the industry can be fixed, to plot a set of data in Excel, fit the points to a linear function, find the slope and extract various quantities from the fit to the data, and more importantly to be able to use mathematical arguments to defend a position. For example, a person who is quantitatively illiterate may not know the effect that a 3% loan has on his finances versus a 5% loan for example. By having students work out the numbers, they will be able to understand what effect a difference of 2% in interest can have on their finances. They will also be required to synthesize, interpret and communicate their results.

The project was designed through a real-life example as students were asked to pick a car and finance it. The issue of debt and interest rate is then generalized to other kind of debt such as students' loans. In the process, students are required to read several articles pertaining to interest rates, car and mortgage loans and the impact of debt accumulation on personal relationships. They will also be engaged in reflective writing about debt, its influence on their life and how to fix problems in the student loan industry.

By making students more financially "literate," the goal for students is to be able to become better decision-makers when it comes to their finances and understand how this knowledge may impact their personal and political choices in the future.

The paper is organized as follows: background information and the project are described followed by the assessment of the project, then the author presents a modification to the project as well as two follow-up projects based on more recent data and articles that can help students develop quantitative reasoning skills.

Background Information

The credit crunch of 2008 has shown the importance of financial and quantitative literacy. It raised awareness about the danger of taking out loans that one cannot afford to pay back. At LaGuardia Community College, the Project Quantum Leap introduces real life problems in various mathematics courses, including introductory college algebra and trigonometry. In this course, every semester, students are assigned three projects related to finance. One of the project assigned during the fall of 2010, was titled *Should You Buy That Car? A Lesson on Interest Rates*. The students are first introduced to a simpler example about car financing and then generalize it to the broader issue of debt by looking at student loans.

The aim of the project was to teach students about how much interest accrues during the life of a loan and the factors that may affect the total interest paid. Students were assigned to read several articles. While some of the articles were technical describing various terms needed to get a loan, others were about the psychological aspects associated with acquiring and accumulating debt, in particular relationship problems between couples that arose because of a large student loan debt accumulated by one party. Students were also asked to write short reflective essays on the issue. This project should help students read, analyze information and think critically. The author also hopes that students will retain few facts from their reading that will help them extend their understanding of interest rates to credit card debt, and generally, engage in sound financial behavior.

The remainder of the paper describes the project, assessment of the project, future modifications to the project and follow-up projects.

Structure of the Project

The project was initially structured into eight parts:

(1,2) Picking the Dream Car and Learning Basic Facts About Car Financing.

The Carnegie Foundation states, "It is Carnegie's belief that community college students will have greater motivation to succeed and persist if their mathematics study is engaging, meaningful, relevant and useful." (http://www.carnegiefoundation.org/quantway)

To apply these principles, the project was designed to have students pick a car of their choice and find its price using an online search engine. This will give each one the freedom to pick what they want and hopefully will motivate them as they move forward.

Since the project involves math and civic engagement, it is necessary for the students to read few articles. The first article is titled *How to Finance a Car and get a Car Loan* (http://usnews.rankingsandreviews.com/cars-trucks/How-to-Finance-a-Car/ accessed June 26, 2011). In it, the author explains what a car loan is and what basic facts a consumer needs to know when they take out a car loan. The article was chosen because it explains all the terms used when trying to finance a car and sheds light on important facts such as who owns the car while one is repaying the loan and what happens when a consumer prematurely stops making payments to the bank.

(3) Financing Options

After students pick their dream car, they were asked to use an online calculator to calculate the monthly payment owed to

TABLE 1. Monthly payment and interest paid on a car loan with a 10% interest rate for various loan terms.

Term of the Loan	**Monthly payment** (for 10% interest rate) in US $	**Total payment after the term of the loan = cash value +Total interest paid** (US $)	**Total interest paid after the term of the loan** (US $)
60 month			
48 month			
36 month			
24 month			
12 month			
Cash value			

finance their car. The rationale behind using an online calculator throughout the project is for students to develop a sense of estimation without having to rely on formulas. The students will be asked first in groups, to estimate the payments, and during the lab hour, they will use the online tool. This will help them judge the validity of the answers obtained using the calculator. They are also required to calculate the total interest paid (given by the same calculator) after the term of the loan and the total amount paid for the car (including interest and principal) after the term of the loan. At the end, students will be required to look at the amortization table. All students made calculations based on an interest rate of 10% (See Table 1). Having students initially estimate payments without relying on formulas is a very important step that G. Cobb (Steen 1997, 78) uses when asking students to estimate correlation before formally introducing them to the formula. In his case, he was promoting each of the four kinds of thinking needed to develop quantitative reasoning. In our case, we are trying to promote the computational and the logical components. The formula can be introduced later in class after the completion of the project.

(4) A Lower Interest Rate

Students are then asked to redo the calculations in Table 1 at a lower interest rate of 6%. In addition, they are asked how a consumer can acquire a lower interest rate. The answer was provided in the first article assigned for them to read.

Students then compared their calculations for Table 1 with their calculations in Table 2. The goal is to help them understand how the interest rate acquired affects their monthly payment and the total interest paid. Table 2 will help students realize the effect of having a lower interest rates on their monthly payment and how much it can help them save during the term of a loan. When comparing the first two columns, students should be able to understand and interpret the data. In particular, for those who don't understand what a 4% difference in interest might have on their finance, this is a clear example that will show them how much money they will save a month if they were to get a lower interest rate.

Parts 3 and 4 introduce students to various factors that affect the total amount of money they will end up paying and should give them an idea about which options they would feel more comfortable with if they were to take out a car loan.

TABLE 2. Monthly payment and saving for 6% versus 10% interest rates.

	Monthly payment for 6% interest rate in US $	Monthly payment for 10% interest rate in US $	Monthly saving in US $
60 month			
48 month			
36 month			
24 month			
12 month			

Reflection: At this point, in order to assess students' understanding of the prior material, a short reflective essay can be assigned: your friend John is planning to finance a car. He is unsure about his budget, but thinks he can afford a $15, 000 car. He has only $2,000 to put down and he earns about $1500 a month after taxes. John contacts you for advice. What advice would you give him? (Please write a 100 to 200-word letter to John, advising him on how much he should spend on a car, what interest rate he should try to get and how much he can afford in monthly payments).

This essay will reinforce various elements of quantitative literacy as defined by Steen: the use of logical thinking in decision-making, the ability to transfer knowledge to a real-life situation, interpret and communicate mathematical arguments, the ability to estimate numbers and the application of mathematics in a given context.

(5) Adding $50 to the Monthly Payment and the Amortization Table

The students are asked in this part to use the online calculator to calculate how much they would save in interest over the term of their loan if they were to add $50 to their monthly payment. The goal of this exercise is for students to realize that adding a small additional payment to their regular monthly payment will help them not only pay off the loan sooner but will save them a significant amount of money in interest paid to the loaner. Some students, who picked expensive cars, realized that adding a $50 to their monthly payment did not help them at all in paying off the loan sooner. They were then asked to estimate the minimum amount they needed to add to their monthly payment in order to pay off the loan at least three month sooner. They then were asked to reflect as to why some of them saw a difference in the maturity of their loan when they added the $50 whereas others didn't. This will help them understand the effect of the "size" of the debt: adding $50 to a smaller loan has a greater impact than adding $50 to a larger loan.

Students also looked at the amortization rate (online) and saw the breakdown of their monthly payment between interest and principal for the duration of the loan. They were asked to write down their observation as to what happens to the interest paid (every month) as the term of the loan progresses. They also compared the amortization table to the one generated when they added $50.This will help them understand why it is important for them to add extra payments and how the portion of the monthly payment applied towards interest decreases with time.

It is important to note that the amortization table applies to various kinds of loans, especially to home loans (or mortgages). The professor can pause here and ask students how and why the amortization table principle applies to a home loan, for example. This will help the professor assess whether students can transfer the knowledge learned.

(6) Analytical and Graphical Analysis

So far, the students have completed their work through short readings and online calculations. At this point, the instructor introduces graphical analysis/calculation with Excel. The online calculator was used to generate the two sample problems described below where students needed to fit the data to a straight line in Excel. At LaGuardia, students are fortunate to have one lab hour every week that can be used towards reinforcing graphical skills. One of the sample problems represents the monthly payment as a function as of the interest rate; the other represents the total interest paid as a function of time.

This part also serves as an assessment to whether students have understood the concepts of interest rates.

F. Rutherford (Steen 1997, 69) argues that students need to learn how to read and interpret simple graphs, and be able to describe relationships in order to develop quantitative literacy skills. The two problems below illustrate this point.

Sample Problem 1:

Suppose you decide to buy a new car for $ 30000. Suppose that you have no money for a down payment and that you decide to finance the whole amount. The dealer offers several financing option through a local bank. He offers you the option of financing the car over 12 month, 24 month, 36 month, 48 month and 60 month.

Unfortunately, the interest rate was high and set at 10%. If a consumer were to pay cash for the car, they would pay $0 in interest, whereas the table below shows the total interest paid after the term of loan if they were to finance it at an interest rate of 10%.

TERM OF THE LOAN (#OF MONTHS)	TOTAL INTEREST PAID AFTER THE TERM OF THE LOAN
12	$ 1649.72
24	$3224.35
36	$4848.56
48	$6522.12
60	$8244.68

(1) Graph the total interest paid as a function of the term of the loan in Excel. Find the linear function that best fits the total interest paid as a function of the term of the loan. Can you verbally describe the relationship between the two variables?

(2) How much have you paid in interest 30 month after you had purchased the car assuming you financed it?

Sample Problem 2:

Suppose that you finance a car that costs $ 30 000 for 4 years (48 month). You are offered a 3% interest rate. Your friend Jack was offered a 4% interest rate (for the same car and the same term of the loan); Clara was offered a 5% interest rate; Adam a 6% interest rate; and Jessica a 7% interest rate. The table below shows the monthly payment as a function of the interest rate.

INTEREST RATE	MONTHLY PAYMENT
3%	$664.03
4%	$677.37
5%	$690.88
6%	$704.55
7%	$718.39

(1) Graph the monthly payment as a function of the interest rate using Excel. Find the Linear function that represents the monthly payment as a function of the interest rate by graphing the data in Excel.

(2) According to the model, what would the monthly payment be if you were to get a 9% interest rate?

(7,8) Civic Engagement: Dreams of an Education

It is common for students to borrow money to finance their education. Many borrow huge amounts of money and then struggle to repay their loans after graduation. One crucial reality is that you cannot default on a student loan. Student loans must be paid back, no matter what.

Parts 7 and 8 ask students to read two relevant articles about the student loan industry. The first article, tackles the social and personal aspect of carrying a very heavy student loan debt and how it can impact one's life. The article illustrates how one person broke off his engagement for marriage when he found out how much his fiancée's student loan debt was (http://www.nytimes.com/2010/09/04/your-money/04money.html?_r=1 accessed June 26, 2011). Students will be first asked simple questions about the reading, then they will be asked to write a short essay arguing whether the astronomical cost of education in the United States is having a negative effect on marriage using the examples in the readings to support their argument.

The second article exposes some problems with the students loan industry and the bureaucracy that comes with it. After answering several questions about the reading, students will be asked to write a well-organized paragraph that clearly states their opinion of the federally guaranteed student loan system and gives examples to prove their point. Their paragraph should answer several points discussed in article, in particular as to why the government doesn't lend money directly, and how they would change the system if they were in power. This will engage them in citizenship, one important component of the SENCER approach. (http://www.nytimes.com/2009/05/28/opinion/28collins.html accessed June 26, 2011)

Assessment

After obtaining the approval of LaGuardia's Institutional Review Board, the principal investigator (PI) conducted surveys followed by short interviews with former students who took the course with the projects. The survey consisted of six questions listed below, with a summary of students' responses. The sample size was seven.

(1) In the fall of 2010, our last project was on car loans, debt and student loan. What did you learn from that activity?

In response to this question, many students stated that they learned about car loans, how to calculate monthly payments and that they enjoyed using the online tools (at Edmunds.com and bankrate.com) to figure out monthly payment on their car loan. Another student stated that he/she learned how interest rates work and what is considered affordable to him/her versus non-affordable. Another stated that the activity helped him/her understand the issue of debt better and how it affects one's personal life.

(2) What did you find the most interesting?

The responses to this question varied. One student found it interesting how people ruin their credit because they cannot accurately estimate their monthly payment on a loan and another found it interesting to see the breakdown between the interest and the principal portion of the loan. Another student found it interesting to see how the monthly interest payment increased if he/she were to change the price of the car (It seems that the student experimented with the online calculator and picked several cars to see how much interest it had cost him/her). Another student found it helpful to see how adding an extra payment can reduce the total interest paid and the term of the loan. Finally, one student enjoyed reading about the couple that broke up because of the amount of students' loan accumulated by the fiancée.

(3) What did you find the least interesting?

Most students answered nothing, but one of them stated that he/she did not like writing essays for the project and that the project was slightly long.

(4) Is there a particular reading assignment (out of all the readings that were assigned for that project) that you particularly remember? If yes, which one?

Most students agreed that they liked using online tools, some of them did not remember some of the readings in detail, but vaguely remembered that they learned about how a car loan works. One student chose the article about the couple that broke up due to high student loan debt as the most memorable.

(5) Have you made any changes to your financial life after the project?

The responses to this question were very interesting; in summary the students said that the project helped them:

- Realize how important it is to keep track of major purchases
- Not to rely on credit too often

(6) If you had the power to modify this project, how would you do it?

One student mentioned that he/she would eliminate the essay; another said he/she would make the project shorter and ask students to write personal stories about debt, while another student would introduce credit card debt. Finally one student said he/she would ask for less calculation.

In the follow-up interview, students mainly reiterated what they said in the survey. Three particular remarks are worth mentioning: one student mentioned that he/she had postponed buying a car after doing the project, another student mentioned that he/she did not make any changes but will keep what he/she learned from the project in mind and another student said that he/she had no idea what the difference between student loan and financial aid was until he/she took the course with the projects. That student was a recipient of financial aid and after doing the project, he/she learned about the existence of student loan.

Future assessment should focus on whether students retained the relationship between the size of a loan and monthly payments and on their ability to estimate payments on credit cards and other types of loans to see whether the project succeeded in helping students transfer their knowledge.

Overall, the PI was pleased that the students still remember the project about four month after it was given.

A recent article shed the light on how households underestimate payments on credit card debt (www.fdic.gov/news/conferences/soll.pdf, accessed November 8, 2011). To be able to assess students' learning after the completion of this project, and since the PI assigns three projects in her course, a second project was designed that focuses on for-profit colleges.

In the next section, the PI will briefly highlights some modifications to the existing project and and will describe potential follow-up projects and their importance and relevance.

Modifications to the Project

A Pre-Project Drill

In order to enhance the project, the PI has found several ways to help students apply quantitative reasoning skills. Before the project is assigned, a guided problem can be given to the class. The problem, a drill exercise, can be done in groups.

Students would be asked to finance a $30 000 car loan. The interest rate on the loan is 6% and the term of the loan is 4 years (48 month).

The aim is to have the student estimate a) the monthly payment on the loan, b) the same monthly payment if their interest rate goes down (for the same term of the loan) c) the same monthly payment if the term of the loan is longer (6 years for e.g.), for the same interest rate (6%).

This step will prepare students for the project by having them discuss their choices among each other. They will also need to explain and defend their choices by arguing. To help them, the instructor can initially ask students to estimate the monthly payment if the interest was 0%! One can then give several choices for the answer to the problem. Having students argue their choices could help the professor learn about any misconception they might have about the topic.

i) The monthly payment for a 6% interest, a 4-year loan is approximately:

A) $625
B) $700
C) $1000
D)$1300

ii) The monthly payment for a 4% interest, a 4-year loan is approximately:

A) $625
B) $657
C) $700
D)$800

iii) The monthly payment for a 6% interest, a 6-year loan is approximately:

A) $625
B) $300
C) $500
D)$1000

iv) Adding $50 to your monthly payment if the loan was for 4 years at 6% interest will help you pay off your loan:

A) 1 month sooner
B) 3 month sooner
C) 5 month sooner
D) 1 year sooner

These questions could help students develop number sense without relying on formula to estimate payments and to defend their choices. Question iv) can help the instructor assess whether students can be engaged in higher order reasoning.

This drill problem tests their prior knowledge and attitudes about interest rates. Students can then input these data in the online calculator, and the professor can ask them if there is a discrepancy in the answers. If there is, then the professor can ask them to explain the reason for these discrepancies.

Based on students' feedback, the PI realized that the project was a bit long, so the project can be given in the future with one sample problem (part 6 of the project) instead of two.

A Follow-up Project: Should For-Profit Colleges Receive Federal Funding?

Part 1:

At LaGuardia Community College, since we give three projects in a given semester, a follow-up project can be designed to focus on students' loan and the burden it is creating on graduates. The project given above exposes students to debt in general. In the follow-up, the professor can focus on quantitative reasoning and critical thinking.

As a start, the professor can show students the graph below (Figure 1) and ask for their observations and interpretations: Which one is increasing at a faster rate, credit card debt, or student loan debt? This will help reinforce the visual/dynamic and the interpretative components of quantitative reasoning as defined by Cobb (Steen, 1997).

From there, the professor can ask students to explain and hypothesize as to why this is the case. Then the students will be directed to read the entire article (http://www.nytimes.com/2011/04/12/education/12college.html accessed June 26, 2011) where the idea of for-profit- colleges is introduced. The professor can also ask students to weigh the risks versus the benefits of carrying a hefty student loan debt.

Next, the professor will make use of a recent report released by the Institute for Higher Education Policy (IHEP) that focuses on delinquency and default rate in the student loan industry. The report is lengthy but the professor can make use of some data and some excerpts to help students understand the reasons behind these problems and the population that is most vulnerable to delinquency (http://www.ihep.org/publications/publications-detail.cfm?id=142 accessed June 26, 2011).

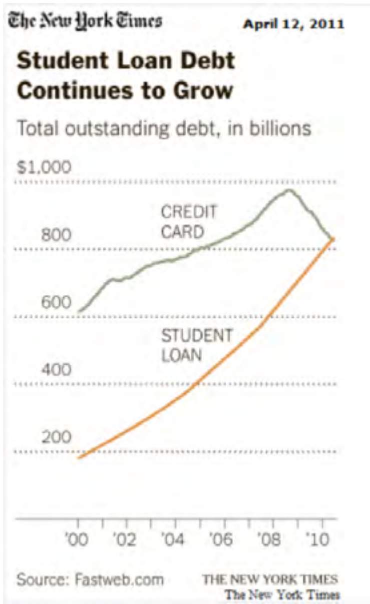


FIGURE 1 Outstanding debt for student loan versus credit card, (http://www.nytimes.com/2011/04/12/education/12college.html accessed June 26, 2011).

Before introducing parts of the actual report of the IHEP, the professor can ask students to independently research for-profit colleges. Samples questions can include:

(1) What is the difference between for-profit and non-profit colleges?

(2) What is the percentage of colleges in the United States that are for-profit?

(3) Do for-profit colleges receive any federal funding?

To help students answer those questions, the instructor can direct them to an article (http://www.huffingtonpost.com/2011/04/25/for-profit-colleges_n_853363.html?page=1 accessed June 26, 2011) focusing on pages 1 and 2 where they can read about the for-profit colleges industry.

When taking excerpts from the IHEP report, the professor can point to the section that explains the difference between default and delinquency.

The report is very rich in data and the analysis presented there would help raise awareness about delinquency in the student loan industry and would reinforce quantitative literacy skills. One example that can be introduced in the project is a table (Table 3) that includes the percentage of 2005 borrowers who were delinquent or who have defaulted on their student loans.

Based on the table, the professor can ask the following questions:

a) What difference does one notice among the percentage of borrowers who became delinquent without default, versus those who had defaulted, and what kind of institutions they come from.

Loan Status of 2005 Borrowers by Last Institution Attended and Graduation Status

OF THOSE WHO LEFT WITHOUT A CREDENTIAL	% OF BORROWERS WHO BECAME DELINQUENT WITHOUT DEFAULT	% OF BORROWERS WHO DEFAULTED	% OF BORROWERS WHO WERE DELINQUENT OR DEFAULTED
Public four-year	30	15	45
Private nonprofit four-year	27	11	38
For-profit four-year	34	30	64
Public two-year	39	27	66
For-profit two-year	26	50	76
All	32	23	55
OF THOSE WHO GRADUATED,			
Public four-year	15	4	19
Private nonprofit four-year	13	5	18
For-profit four-year	21	14	35
Public two-year	27	15	42
For-profit two-year	27	30	57
All	20	13	33

TABLE 3 (Taken from: http://www.ihep.org/publications/publications-detail.cfm?id=142 page 23, accessed June 26, 2011).

b) Do you see any economic advantage for graduating from college (versus leaving without completing your credentials)? Why?

Another useful excerpt from the report focuses on the similarities and differences on borrowers who are delinquent or who defaulted (see page 22 of the IHEP report http://www.ihep.org/publications/publications-detail.cfm?id=142).

The instructor can ask students to analyze the reasons of these similarities/differences, and why borrowers from the for-profit colleges are more vulnerable to default than any other student population. These questions would reinforce critical thinking skills.

Part 2

In conclusion, students can be asked to write a short essay answering the following questions:

Should the for-profit "industry" be regulated? Should for-profit colleges receive federal aid, why or why not? Should for-profit institutions be allowed to make donations to candidates running for public office? Students will be asked to base their answers on the assigned articles, the data presented, and any other reliable articles or source of information they might find on their own.

Possibility of a third project:

A third project and final project can be devised based on the first two projects. Its aim is to implement the work by other SENCER model course (http://myweb.lmu.edu/tzachari/SENCER.html, accessed November 8th, 2011) and to assess whether students have retained the information from the previous two projects. The third project will consist of three parts. The first one will assess retained information, the second part will borrow ideas from other SENCER model courses and the third part will synthesize the information in a reflection on citizenship. These parts will be described next.

Part 1

Students should be asked to estimate quantities that require the use of the computational and logical components of Cobb's cognitive emulsion of quantitative reasoning as a start. The following problem will also assess whether they retained any information from the previous projects and whether their ability to develop number sense and estimates has been improved.

i) Judy had accumulated a balance of $4000 on her credit card. The interest rate on her card is 15%. How long will it take her to pay off the balance if she were to make a) $100 in monthly payments, b) $300 in monthly payments?

ii) George, who had accumulated a similar debt, had a better credit history and managed to get a credit card with a 5% interest rate instead. How long it will take George to pay off his own debt if he were to make a) $100 in monthly payments, b) $300 in monthly payments?

Next, students will be presented a graph (figure 2). The questions below will reinforce the visual and the verbal (interpretative components) of Cobb's cognitive emulsion of quantitative reasoning.

The graph is extracted from a recent article about how households underestimate payments on credit card debt. This issue is relevant to students and would be a great place to start since it correlates with the idea that students need to develop better quantitative reasoning skills to make better decisions. Students will be asked to: 1) explain the meaning of each graph, 2) interpret why the lined graph is above the dotted graph, and its significance 3) predict the behavior of each graph for interest rates above 30%, 4) explain why the lined graph grows much faster than the dotted graph, 5) explain why the gap between the two graphs widens as the interest rate increases and 6) explain the significance of carrying a debt

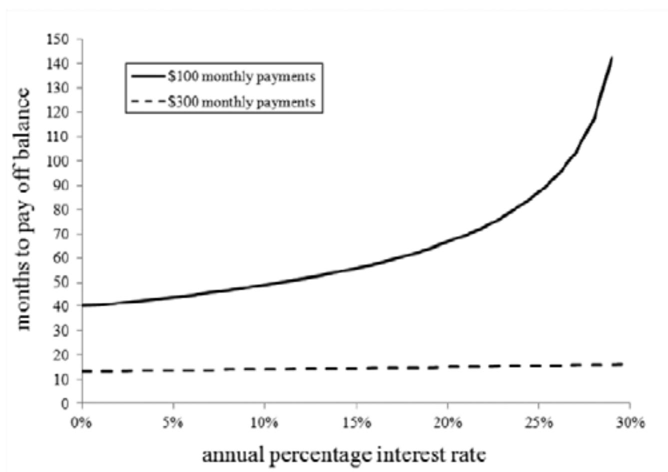


FIGURE 2 Effect of the monthly payment amount and interest rate on the time to pay off a $4,000 loan. (www.fdic.gov/news/conferences/soll.pdf, accessed November 8, 2011)

with an interest rate higher than 20% if one is to make $100 in monthly payments.

Students should then compare their estimates with the ones presented in the graph and explain the reason for any significant discrepancies.

Part 2

As stated earlier, Zachariah, Larson and Dewar (http://myweb.lmu.edu/tzachari/SENCER.html, accessed November 8, 2011), designed a course implementing the SENCER model. One of their lessons focuses on the student loan model. The project is a case study of the finances of one particular person. It is very interesting and can be implemented as a follow up project after exposing students to the concept of loans and to issues related to the student loan industry. One of the aims of the project described in this paper is to help students estimate and develop number sense as a start. After familiarizing themselves with the basic principles of debt and the student loan industry, the model presented by Zachariah, Larson and Dewar can be adapted to look in details at a person's financial situation. In particular, since it is a third project in an introductory college algebra class, the project will not be elaborate in asking students to look at all kinds of student loan (E.g. Perkins loans, Stafford loans, PLUS loans or Federal consolidation loans), but will present students with a case-study of a person's financial situation. A suitable example is described below.

John has just graduated from college. He got a job that pays him $60,000 yearly (Gross). He is single and has no dependents. He has recently bought a car for $15,000. He put $3000 down and financed the rest for 5 years at a 6% interest rate. He also has taken out student loans when he was a student and needs to start repaying them. He has taken $5,000 in loans, every year of study for four years. The terms of his student loan are: Annual interest rate 5% (fixed), 10 year term that needs to be paid monthly. He currently has no savings and only $2500 in his checking account. He has a credit card balance of $833. Assume that John needs to start repaying his loan immediately.

John is currently living with his parents and pays no rent. Students can be asked to estimate (without relying on the formula) his monthly bills by filling out a spreadsheet similar to the one presented by Zachariah, Larson and Dewar (including payments on his car and student loan) and his take-home pay after taxes. They will also be asked to estimate John's monthly savings if any. They then can be asked to accurately calculate the payments on his car loan and student loan, and compare it with their estimate.

Part 3

Based on their spreadsheets, students will be asked to write a detailed essay arguing whether John will be able to retire at age 65. They will assume that John will be getting a 3% raise every year and that he will remain single.

One student will be asked to volunteer to discuss his answer to the question with his peers. In the process, students in class will be asked to mentally estimate how the numbers in the spreadsheets get modified if John's circumstances were to change, such as if he were to get married or to buy a home.

Students could also be asked to predict how John's financial situation would change if he had not taken out those student loans. They can also be asked to research the "pay as you earn" program recently passed by president Obama and state their opinion about it and if such program would have benefited John in this case.

This project contains all of the components of Cobb's four different kinds of thinking that form the cognitive emulsion of quantitative reasoning: the computational and logical components are presented in the three parts of the project, the visual component is presented in part 1, and finally the verbal and interpretative component in part 3.

Conclusion

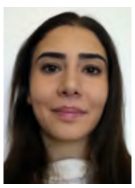
The projects described in this paper can help students develop quantitative reasoning and critical thinking skills, build confidence in estimating quantities, synthesize, reflect on what they learned and use mathematical arguments and logical thinking to defend a decision. They also aim at engaging students in issues that are relevant to them. The first project, for example, exposes students to debt in general: students learn about how car loan payments work, the concepts of interest rates, the danger of carrying too much debt and financing items they cannot afford. It also exposes them to the student loan system and problems with the way it is administered.

The second project is directed towards critical thinking and as a follow-up to the first project. It engages students in thinking critically and effectively about the civic issue of federally funding for-profit colleges.

A final project can be devised as a case study of a personal financial situation and can be designed in such as way to assess whether students retained previous information. It also aims at enhancing students' verbal and interpretative skills, and the use of mathematical arguments.

Quantitative reasoning has been implemented across the curriculum to look at other important issues such as: income inequality in the U.S., fairness in voting, bankruptcy, wealth and democracy, fair divisions and pensions (Root, 2009). This approach can empower students and must be continually improved so that a college education can provide an education to the whole person. Coupling quantitative reasoning to the SENCER model has the advantage of providing the civic framework to help students become better critical-thinkers and better decision-makers for their sake and the sake of the society they live in.

About the Author



Reem Jaafar (Ph.D., 2010, Graduate Center of the City University of New York) is an assistant professor in the Department of Mathematics, Engineering, and Computer Sciences at LaGuardia Community College, New York. Previously, she was an adjunct teaching physics at Lehman College, CUNY. Dr. Jaafar's current areas of research are: nanoscience and mathematics pedagogy.

Acknowledgements

The author would like to thank the leaders and the participants of the Project Quantum leap at LaGuardia as well as members of LaGuardia's Center for Teaching and Learning, in particular Roslyn Orgel and Carolyn Henner-Stanchina for helpful discussions and feedback.

References

Auto Rates in New York Metro, New York http://www.bankrate.com/funnel/auto/auto-results.aspx?market=2&prods=74 (accessed June 26, 2011)

Betne, Prabha. 2010." Project Quantum Leap and SENCER at LaGauardia Community College", http://www.seceij.net/seceij/summer10/project_quantum.html (accessed June 26, 2011)

Collins, G. 2009. *When Sallie Met Barack* http://www.nytimes.com/2009/05/28/opinion/28collins.html (accessed June 26, 2011)

Cunningham A. and Kienzl, G.S. 2011. *Delinquency: The Untold Story of Student Loan Borrowing*, http://www.ihep.org/publications/publications-detail.cfm?id=142 (accessed June 26, 2011).

Deaton, J.P. 2008. *How to Finance a Car and Get a Car Loan*, http://usnews.rankingsandreviews.com/cars-trucks/How-to-Finance-a-Car/ (accessed June 26, 2011)

Fowler H. 2003. A dictionary of modern English usage (end rev. ed.). New York: Oxford University Press.

Kirkham, C. 2011. *For-Profit Colleges Mount Unprecedented Battle For Influence In Washington*, http://www.huffingtonpost.com/2011/04/25/for-profit-colleges_n_853363.html?page=1 (accessed June 26, 2011).

Lewin, T. 2011. *Burden of College Loans on Graduates Grows* http://www.nytimes.com/2011/04/12/education/12college.html (accessed June 26, 2011).

Lieber, R. 2010. *How Debt Can Destroy a Budding Relationship* http://www.nytimes.com/2010/09/04/your-money/04money.html?_r=1 (accessed June 26, 2011)

Paulos J.A. 2001. Innumeracy: mathematical illiteracy and the consequences. New York: Hill and Wang.

Quantitative Literacy through Community-Based group Projects http://myweb.lmu.edu/tzachari/SENCER.html (accessed November 8th, 2011)

Root, B. 2009."Social Justice Through Quantitative Literacy: A Course Connecting Numeracy, Engaged Citizenship, and a Just Society". Lewis & Clark Graduate School of Education and Counseling Volume 18 (n3): page–37-43.

SENCER. 2009. The SENCER Model Series http://www.sencer.net/Resources/models.cfm (accessed on June 26, 2011)

Soll, J. Keeney R. and Larrick R. 2010 *Consumer Misunderstanding of Credit Card Use, Payments, and Debt: Causes and Solutions* (www.fdic.gov/news/conferences/soll.pdf, accessed November 8th, 2011)

Steen L. 1997. Why Numbers Count: Quantitiative Literacy for Tomorrow's America. The College Board.s

Steen L. 2001. Mathematics and democracy: The case for quantitative literacy. National Council on Education and the Disciplines.

Steen L. 2004. Achieving quantitative literacy: an Urgent Challenge for Higher Education. The Mathematical Association of America.

PROJECT
REPORT

Assessment of the SENCER Teaching Model at Indiana State University After Two Years

Peter J. Rosene
Indiana State University

M. Ross Alexander
Indiana State University

James H. Speer
Indiana State University

Abstract

We have assessed the Science Education for New Civic Engagements and Responsibilities (SENCER) Teaching Model at Indiana State University after two years of implementation using our traditional Student Instructional Reports (SIR) and the SENCER Student Assessment of Learning Gains (SALG). We compared SIR results from before and after implementation of the SENCER Teaching Model within the same faculty teaching introductory laboratory science courses in the natural sciences. Three faculty members taught through the transition to the SENCER course and volunteered to provide their evaluation scores for this assessment. We found that the transition to a SENCER course was not always easy with one faculty member declining in evaluation scores while two others increased. The majority of open responses were positive about the new course and we would recommend the adoption of the SENCER Teaching Model with the expectation that further faculty development may be required in some cases.

Introduction

Indiana State University (ISU) has a long history and dedication to experiential learning and community engagement. That is why the Science Education for New ivic Engagements and Responsibilities (SENCER) Teaching Model was recognized as an important direction for Science, Technology, Engineering, and Mathematics (STEM) education at ISU. We were first introduced to this teaching model at a regional conference at Butler University in December 2008. We sent a team to the SENCER Summer Institute in Summer 2009 that was composed of two faculty, a student, and representatives from the Office of Sponsored Programs, the Center for Public Service and Community Engagement, and the Center for Collaboration and Innovation in Teacher (CCITE). By the end of that summer, SENCER was incorporated into the president's new strategic plan and funding was allocated for the development of the SENCER Teaching Model at ISU. Funds were provided to advance SENCER at ISU with the goal of spreading this teaching model to other faculty on campus and advertising SENCER classes across campus to students and to their parents. With these funds, we created a Student Leadership Team linked with SENCER bringing an entirely new aspect of involvement from other SENCER programs; providing students the opportunity to have a direct effect on the curriculum. The team was designed to have a graduate student oversee the activity of six undergraduate students representing different academic disciplines on campus. These different disciplines add new skills and insights to pushing forward the ideals of SENCER.

Our program is by no means new to the academic world as the roots of SENCER began in the early 1990s at Rutgers University with the study and education of the HIV/AIDS virus where administrators like David Burns and educators like Karen Oates saw the necessity to advance research on the social and biological effects of AIDS as well as provide informative education for students (Sheardy 2010). Along with the educational principles of SENCER comes the integration of civic engagement giving curriculums a wider scope and allowing students opportunity to see their actions affect their field of research as well as the community. The connection between SENCER and the community is essential as a learning tool because it connects the students with their communities, hopefully instills in them a habit of helping their communities, and it enables them to work on important issues (SENCER 2010).

After two years of implementing the SENCER Teaching Model at ISU, we are now able to assess the effect of the early stages of this program. Traditionally, we have used the Student Instructional Reports (SIR) to assess our courses across campus and we have comparable surveys for our 100-level natural science courses before and after the development of SENCER classes at ISU. The SIR assessment gives a general quantitative rating for each question on a scale of one to five (five being most positive and one being least positive). However, as Stephen Carroll points out in his essay on class evaluation in SENCER courses, these evaluations are merely blunt instruments that do not attack or pin point a short-coming in a class (Carroll 2010). Instead of evaluating the actual course itself confronting the curriculum foundation, these evaluations rate the professor giving practically no insight to student learning.

Alone the SIR discloses little in relation to the overall curriculum performance, so to get a clear understanding of how and if our performance has been a positive influence on student learning at the university we needed to use a tool that provides more insight into our students' experience in these courses. Therefore, we also administered the SALG (Student Assessment of Learning Gains: http://www.salgsite.org) analysis tool used by many SENCER programs across the country such as the Texas Woman's University where it has allowed professors to gain an understanding of how students perceive the content as well as the gains in 21st Century Skills received through these courses (Maquire and de Rosa 2010). The SALG test contains quantitative question types where, like the SIR, students give answers in degree on a scale of one to five, but unlike the SIR the individual professors have the ability to tailor questions to their specific classes and curriculums giving a much more precise tool for evaluation. The SALG also asks open response questions which enable qualitative assessment and a broader examination of student gains from the course.

In the areas of civic engagement and scientific advancement through student learning, the ISU SENCER Team has made considerable gains in developing a curriculum in the Earth and Environmental Systems Department, and after two years of implementation we would like to evaluate the effect of the SENCER teaching model in these courses. In order to do this we will evaluate our "flag ship" courses in the Department of Earth and Environmental Systems: ENVI 110 Introduction to Environmental Science and ENVI 460 Conservation of Natural Resources. Both of these courses are part of our foundation studies (also called general education) courses so students from across campus (both majors and non-majors) have the opportunity to experience these courses. Our objectives with this work are to determine if the SENCER Teaching Model improves student learning at ISU and to evaluate the effectiveness of these courses in teaching 21st Century Skills (such as critical thinking).

Methods

Although the SALG provides a much more precise instrument for curriculum analysis giving us a better understanding of our students' learning with testing at the beginning and end of the semester, we have also decided to use the SIR survey as a supplemental tool to assess change from pre to post SENCER adoption. We have only recently implemented the SALG assessment for our new SENCER courses, so we needed an alternative tool to be able to analyze courses before and after implementation. We will use the SIR assessment for temporal comparisons and use the SALG assessment to provide a clearer picture of our SENCER courses after implementation.

SIRs allow us to compare with courses that were taught for ten years prior to the adoption of the SENCER model. At the time of the adoption of the SENCER Teaching Model our department changed numbers from the Department of Geography, Geology, and Anthropology to the Department of Earth and Environmental Systems. In this process the content from two basic lab science courses of Geography 111: The Physical Environment and Geology 160: Introduction to Earth and Sky was combined into a new course called Environmental 110: Introduction to Environmental Science. The same instructors taught these courses but there was some change in the course information. This was the most accurate comparison that we could provide with pre- and post-adoption of the SENCER Teaching Model. We compared the responses from seven questions on the SIR from three faculty members that had taught these previous classes for the last ten years and are now currently teaching the new Environmental Science course. We specifically chose these seven questions from the SIR survey because they dealt with student learning and engagement with the course material, as do the questions in the SALG assessment.

The SIR scores of three professors who had adopted the new SENCER pedagogical techniques were analyzed for two time periods: pre-SENCER (2000—Fall 2009) and post-SENCER (Spring 2009). Due to the recent adoption of the SENCER program at ISU, all professors analyzed only had one post-SENCER course available for analysis. However, all professors taught at least three introductory courses prior to the SENCER program's adoption.

We also analyzed long-response questions in the SALG to get a better understanding of the students' gains in the ENVI 110: Introduction to Environmental Science and ENVI 460: Conservation and Sustainability courses. These questions allow us to see firsthand testimony from students on their evaluation of the class and their learning gains, providing a valuable guide to changes in the course curriculum. We chose to focus our evaluation on the following questions relating the students' proficiency and understanding of the course material:

> "Please comment on how the CLASS ACTIVITIES helped your learning,"
>
> "Please comment on what SKILLS you have gained as a result of this class,"
>
> "Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject,"
>
> "What will you CARRY WITH YOU into other classes or other aspects of your life?"

Results

Of the three professors that were examined two distinct categories emerged (Professor Type A and Professor Type B; Figures 1 and 2). Professor 1 fell into the type A category, and was found to have lower SIR scores in the post-SENCER era (mean Δ: -0.41; Table 1), with the greatest loss occurring on question 40, the overall quality of the instruction (Table 1 and 2). Professors 2 and 3 fell into the Type B category, because they saw improvement in their SIR evaluation scores in almost all areas. For professor 2 the implementation of the SENCER program resulted in increases in all of the analyzed questions (Tables 1 and 2), with a mean difference of +0.43 (Table 1). The question resulting in the greatest increase in SIR scores was question 33 (active involvement of students in their learning; Tables 1 and 2). The question showing the least improvement was question 31 (+0.06; interest in the subject matter; Tables 1 and 2). Professor 3 saw increases in SIR scores following SENCER implementation across all questions except for question 40 (overall quality; Tables 1 and 2).

TABLE 1. Differences (Δ) of pre- and post-SENCER scores for each professor sampled for each SIR question examined. Also mean Δ in scores for all questions examined is presented as well. See Figure 1 and 2 for summary of the questions.

Prof.	Question	22	29	30	31	32	33	40	Mean Δ
1	Δ	-0.39	-0.54	-0.18	-0.46	-0.34	-0.28	-0.69	-0.41
2	Δ	+0.46	+0.49	+0.49	+0.06	+0.53	+0.63	+0.37	+0.43
3	Δ	+0.47	+0.33	+0.47	+0.40	+0.54	+0.06	-0.04	+0.32

TABLE 2. Mean (± SD) SIR results from pre- and post-SENCER eras for three professors at Indiana State University. Pre-SENCER era includes introductory classes taught by that professor from 2000—fall 2009. Post-SENCER era includes equivalent introductory courses taught spring semester 2009.

	Question	22	29	30	31	32	33	40
PROF. 1								
	Before	3.19 ± 1.10	2.65 ± 1.0	2.74 ± 0.94	2.63 ±1.16	2.74 ± 1.08	2.52 ±1.09	3.18 ±1.05
	After	2.80 ± 1.32	2.11 ± 1.13	2.56 ± 1.05	2.17 ± 1.19	2.40 ± 1.14	2.24 1.23	2.49 ± 1.17
PROF. 2								
	Before	4.14 ± 0.82	3.57 ± 1.01	3.47 ± 0.94	3.40 ± 1.11	3.45 ± 1.01	3.50 ± 0.98	4.05 ± 0.84
	After	4.60 ± 0.58	4.06 ± 0.95	3.96 ± 0.82	3.46 ± 1.05	3.98 ± 0.99	4.13 ± 0.76	4.42 ± 0.71
PROF. 3								
	Before	3.88 ± 0.84	3.44 ± 0.88	3.88 ± 0.81	3.31 ± 1.02	3.30 ± 0.92	3.25 ± 0.94	3.98 ± 0.78
	After	4.35 ± 0.66	3.77 ± 0.76	4.35 ± 0.96	3.71 ± 0.94	3.84 ± 0.78	3.90 ± 0.87	3.94 ± 0.67

TABLE 3. Summary of qualitative assessment collected from the ENVI 110 class for four selected SALG questions.

Question	n	Positive	Negative	Mixed
How Class Activities Aided Learning	**283**	212 (75%)	60 (21%)	11 (4%)
What Skills Gained	**211**	186 (88%)	16 (8%)	9 (4%)
Changed Attitudes Towards Subject	**252**	222 (88%)	24 (10%)	5 (2%)
Transferable Experiences	**186**	168 (90%)	10 (5%)	8 (5%)

A −0.04 difference was observed between the two eras on that specific question. This negative difference was unusual, because positive differences were seen in scores across all of the other questions. The greatest score increase for Professor 3 occurred with question 32 (+0.54; this course helped students think independently about the subject matter; Tables 1 and 2). Qualitative assessment methods within the SALG instrument were also used to determine how students perceive the change in pedagogy. Overall, 85% of the comments from select SALG long-response questions were positive (Table 3). Students commented on how activities throughout the course aided in their learning (75% pos., 21% neg., 11% mixed), what skills they gained as a result of the class (88% pos., 8% neg., 9% mixed), how their attitudes changed towards the subject material (88% pos., 10% neg., 2% mixed), and how experiences from the current course could be transferred to other subject areas (90% pos., 5% neg., 5% mixed; Table 3).

Discussion/Conclusion

After two years of using the SENCER teaching model at Indiana State University we found cases of both easy and difficult implementation of the model. Professors who were able to integrate the model seamlessly into their courses saw approximately 0.5 point increases on a five-point scale across most questions sampled, when already starting near a 4.0 on the scale (Figure 2). However, other professors found integrating the model into their courses more difficult, resulting in approximately 0.5 point decreases across most questions sampled (Figure 1). However, this is to be expected. Initially, the model may not be compatible with all teaching styles, and those professors already using many of the principles of the SENCER model will, undoubtedly, find implementation easier. This is not to discourage those who wish to alter their teaching style to allow for a more active learning experience. However, faculty development time must be given for these faculty members to become comfortable with this new teaching style.

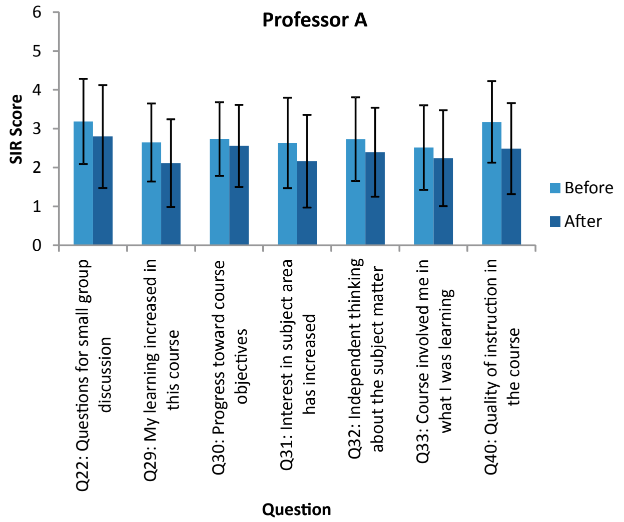


FIGURE 1. For professor type A the post-SENCER SIR scores were lower than pre-SENCER scores for all questions (Number of respondents per question was 39-85 before and 35-51 after implementation).

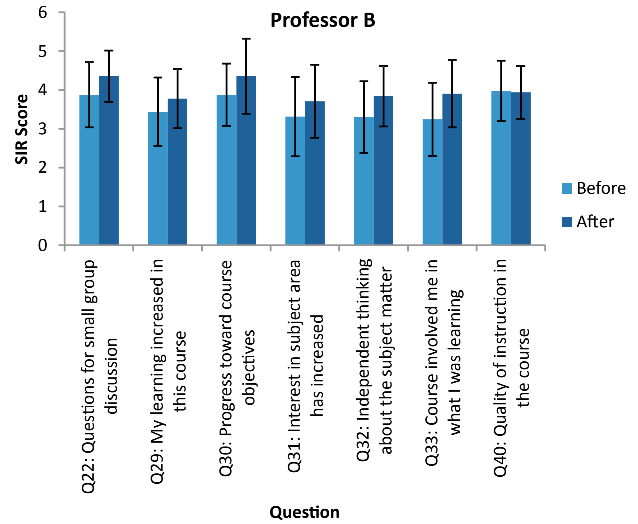


FIGURE 2. Professor Type B displayed increases in SIR scores from the pre- to post-SENCER era across all questions examined (Number of respondents per question was 791-910 before and 77-79 after implementation).

Combining both quantitative and qualitative data from the SIR and SALG instruments shows that students are self-identifying improvements in 21st Century Skills in the courses. The long-response questions from the SALG allow students to divulge more information than a quantitative measure can assess (Table 4; Appendix A).

Our most basic objective was to determine if the SENCER courses helped to improve student learning. We found that the vast majority of open responses from the SALG assessment were positive towards these classes (85%; Table 3). Furthermore, we see that most students improved the rating of their learning when we examined the same professors over time in the pre and post SENCER eras. These improvements were even made when students were already scoring the faculty close to 4.0 on a 5 point scale.

At Indiana State University we plan to continue to add more courses to those departments who already house current SENCER classes and spread the model across campus to include departments outside of the STEM fields. The results presented here are from the very early stages of adoption of the SENCER Teaching Model, and we hope to continue assessing this model as it matures on our campus. In the future

TABLE 4. Sample quotes from the SALG assessment

"The subjects in this class have made me more aware of the world. I know more about it and feel more educated to talk about it with other people."
"When any student is getting hands on time, it automatically interests the student more, therefore enabling you to learn better."
"The importance of the topics and how they related to each other made learning the information easier."
"My understanding of science has changed greatly. Before I was never interested in science, now I am."
"This class boosted my critical thinking skills and I have already been able to incorporate many of the things that I have learned in this course into my other courses."

we will continue collecting SIR and SALG data and make valid statistical comparisons when the post-implementation dataset has reached an adequate size. However, given these results we are confident that SENCER classes are being received positively by the majority of the students that experience them.

About the Authors

Peter J. Rosene is a political science and legal studies double major at Indiana State University in the pre-law program. He is a member on the ISU SENCER Student Leadership Team specializing in grant writing and data analysis for SENCER courses. He is currently finishing his senior year of undergraduate studies and looking to attend law school in Fall 2012.

M. Ross Alexander is a second year master's student at Indiana State University, and has been the graduate student representative on the Student Leadership Team since the fall of 2010. He graduated from Hanover College in 2010 with B.A.'s in biology and chemistry. Currently he is studying dendrochronology with Jim Speer, and investigating the residence time and nutrient cycling of coarse woody debris in Eastern Deciduous Hardwood forests of Indiana.

James H. Speer is a professor of geography and geology at Indiana State University and has been there since 2001. His main research area is in dendrochronology and using tree rings to reconstruct ecological phenomenon such as fire and insect outbreaks. He teaches environmental science and sustainability classes and has worked with the SENCER Teaching Model since 2009.

References

Bachofer, S.J. 2010. "Studying the Redevelopment of a Superfund Site: An Integrated General Science Curriculum Paying Added Dividends." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 117-133. Oxford: Oxford University Press.

Burns, W. 2010. "SENCER in Theory and Practice: An Introduction and Orientation." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 1-23. Oxford: Oxford University Press.

Carroll, S., 2007. "SALG Site." http://www.salgsite.org/ (accessed June 20,2011).

Carroll, S.B. 2010. "Engagning Assessment: Using the SENCER-SALG to Improve Teaching and Learning." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 149-198. Oxford: Oxford University Press.

Eichler, J.F. 2010. "Ground Level Ozone in Newton County, GA: A SENCER Model for Intorductory Chemisty." In Science Education and Civic Engagment: The SENCER Approach, R.D. Sheardy, ed., 109-116. Oxford: Oxford University Press.

Faszewski, E., J. Duggan, ed. 2007. "Environmental Forum: The Cornerstone of a Joint Program in Environmental Science for the Colleges of the Fenway." http://www.seceij.net/files/seceij/science_education_civic_engage.pdf (accessed June 18, 2011).

Illman, D.L. 2010. "Engaging Students in Science Communication." In Science Education and Civic Engagment: The SENCER Approach, R.D. Sheardy, ed., 135-147. Oxford: Oxford University Press.

Jacobsen, L., J. Mistele, ed. 2010. "Please Don't Do "Connect the Dots": Mathematics Lessons with Social Issues." http://seceij.net/seceij/summer10/dont_do_connect.html (accessed June 18, 2011).

Jordan, T. and Reilly, E., 2011. "Science Education & Civic Engagement: An International Journal." http://www.seceij.net/seceij/about.html (accessed June 20, 2011).

Leckrone, K.J. 2010. "Implementing Civic Engagemnet Ideals in Analytical Chemistry." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 85-108. Oxford: Oxford Univeristy Press.

Maguire, C., and J. da Rosa. 2010. "Implementing SENCER Courses at Texas Woman's University." In Science Education and Civic Engagemnt: The SENCER Approach, R.D. Sheardy, ed., 45-61. Oxford: Oxford University Press.

Marcus, J. 2011. "Old School: Four-Hundred Years of Resistance to Change." In Reinventing Higher Education: The Promise of Innovation, Wildavsky, B., A.P. Kelly, and K. Carey, eds., 41-72. Cambridge, MA: Harvard Education Press.

Masthay, M.B. 2010. "Enhancing Chemistry Courses for Non-Majors: Implementation of Simple SENCER Teaching Strategies at the University of Dayton." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 63-84. Oxford: Oxford University Press.

Pfaff, T., A. Erkan, J. Hamilton, M. Rogers, ed. 2011. "Multidisciplinary Engagement of Calculus Students in Climate Issues." http://seceij.net/seceij/winter11/calculus_studen.html (accessed June 18, 2011).

Reilly, E.J. 2010. "The SENCER Models." In Science Education and Civic Engagment: The SENCER Approach, R.D. Sheardy, ed., 25-34. Oxford: Oxford University Press.

Sheardy, R.D., and R.C. Jones. 2010. "SENCER at TWU." In Science Education and Civic Engagement: The SENCER Approach, R.D. Sheardy, ed., 35-43. Oxford: Oxford University Press.

Sheardy, R.D., ed. 2010. Science Education and Civic Engagment: The SENCER Approach. Oxford: Oxford Univeristy Press.

APPENDIX A

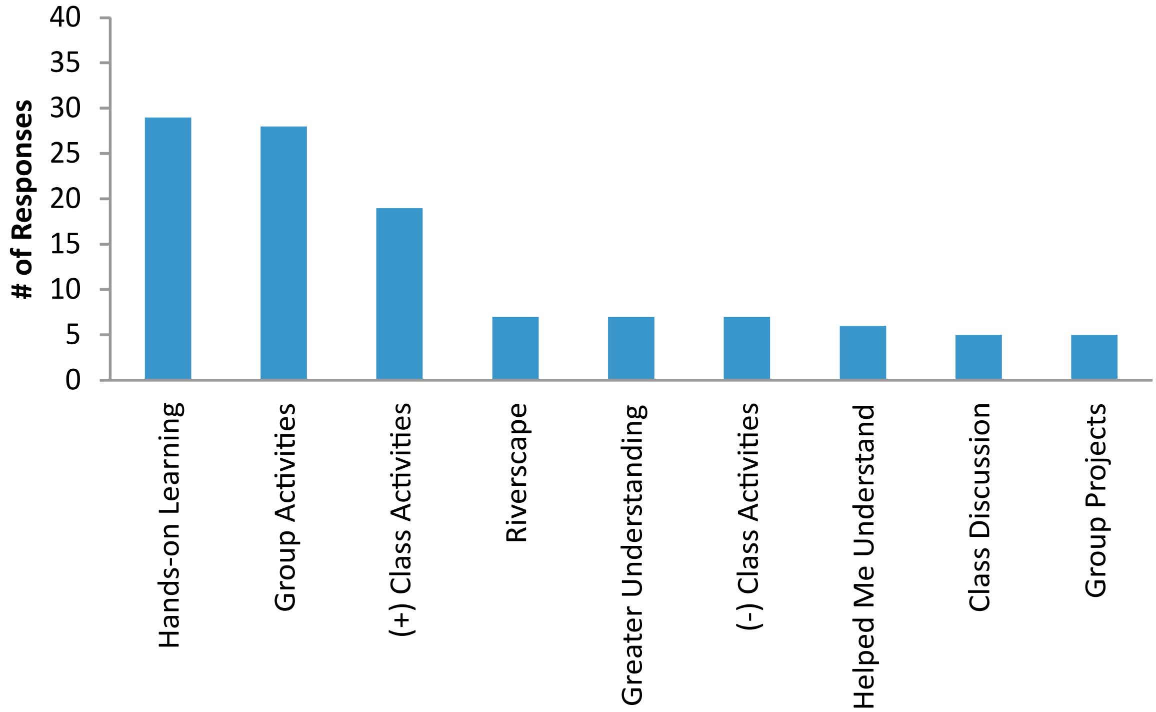


Figure A1: How did class activities help your learning?

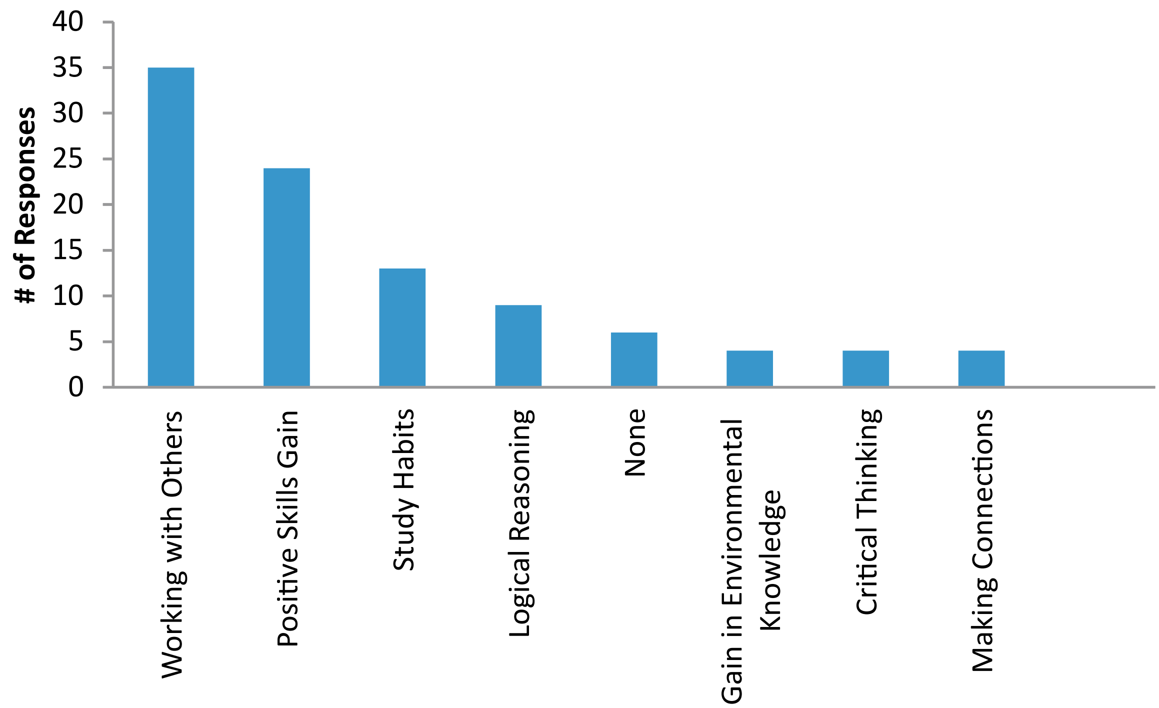


Figure A2: What skills have you gained as a result of this course?

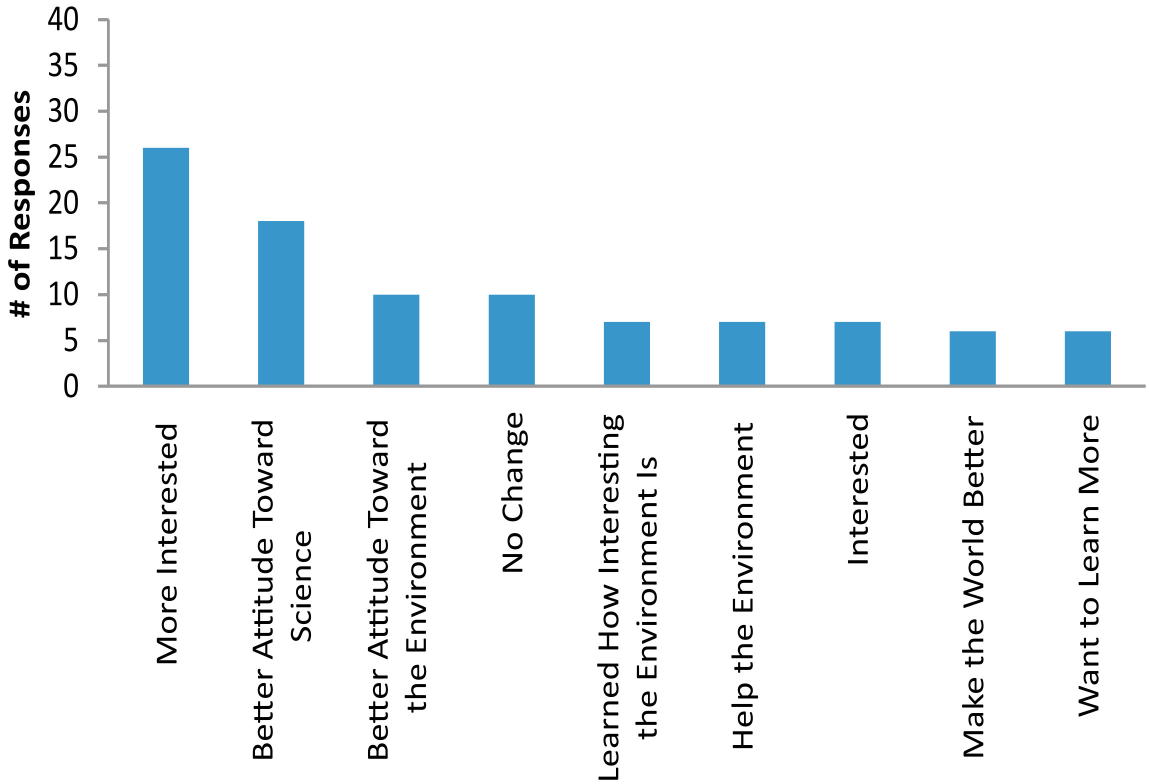


Figure A3: How has this class changed your attitude towards this subject?

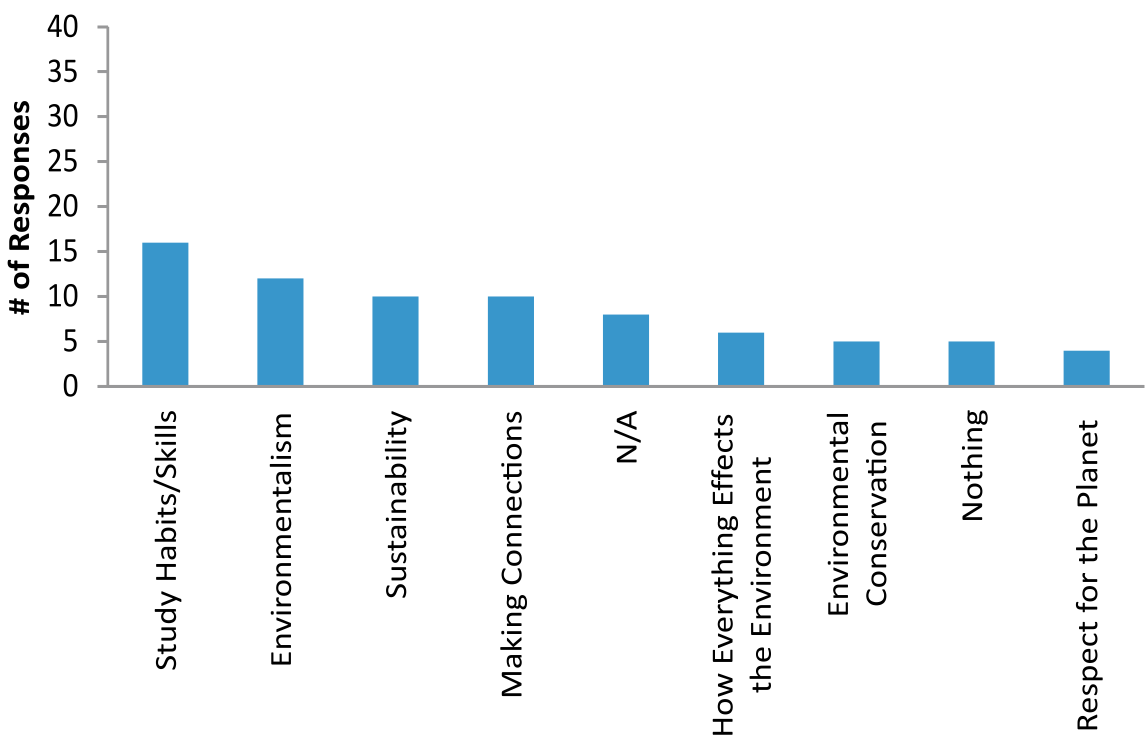


Figure A4: What will you carry with you from this course?