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Science Education and Civic Engagement: The SENCER Approach

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Foreword

The ACS Symposium Series was first published in 1974 to provide a mechanism for publishing symposia quickly in book form. The purpose of the series is to publish timely, comprehensive books developed from the ACS sponsored symposia based on current scientific research. Occasionally, books are developed from symposia sponsored by other organizations when the topic is of keen interest to the chemistry audience.

Before agreeing to publish a book, the proposed table of contents is reviewed for appropriate and comprehensive coverage and for interest to the audience. Some papers may be excluded to better focus the book; others may be added to provide comprehensiveness. When appropriate, overview or introductory chapters are added. Drafts of chapters are peer-reviewed prior to final acceptance or rejection, and manuscripts are prepared in camera-ready format.

As a rule, only original research papers and original review papers are included in the volumes. Verbatim reproductions of previous published papers are not accepted.

ACS Books Department

Preface

This book evolved from a symposium held at the 236th annual meeting of the American Chemical Society in August, 2008 at Philadelphia, PA. The symposium, hosted by the Division of Chemical Education, focused on incorporating SENCER (Science Education for New Civic Engagements and Responsibilities) ideals into science curricula. SENCER embraces the notion that science education should provide students with a strong scientific background as well as the foundation to think critically about global issues. With this foundation, students would be better prepared to engage in civic processes. Many of the contributors to this book were speakers at the symposium while other contributors have been involved with SENCER and are knowledgeable in the theory and practice of science education and civic engagement.

This book was organized to first illustrate the ideals, importance and relevance of SENCER. David Burns, Director of the National Center for Science and Civic Engagement, begins with a description of SENCER philosophy, ideals and strategies aimed at the improvement of science education for both science and non science majors. It should also be mentioned here that David Burns initiated the SENCER program as Principal Investigator on a grant from the Division of Undergraduate Education of the National Science Foundation. Dr. Eliza Reilly follows up with a definition and description of SENCER model courses. These courses have gone through a rigorous review to assure the highest ideals of SENCER and can be used by any educator who wishes to incorporate civic engagement into a science course. Subsequent chapters discuss strategies for initiating and implementing SENCER courses and programs of study. Chapters four through eight are specific examples of different courses incorporating SENCER. The chapter by Dr. Illman discusses the importance of teaching science majors communication skills that will enable them to present science to the general public. Finally, the book ends with a chapter describing the use of SALG (Student Assessment of Learning Gains), an online assessment tool developed specifically for active learning pedagogies, which has also been developed through a National Science Foundation grant.

I would like to thank the Division of Chemical Education of the American Chemical Society for the opportunity to organize the symposium and ACS Books for the invitation to put together this book. I am also indebted to all the authors for their hard work and diligence, not only in the preparations of their respective chapters, but also for their continued efforts to improve science education in America and beyond. Finally, my involvement in SENCER would not have been possible without the support and encouragement of Dr. Ann Q. Staton, Dean of the College of Arts and Sciences at Texas Woman's University.

January 4, 2010

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Chapter 1

SENCER in Theory and Practice

An Introduction and Orientation

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SENCER stands for "Science Education for New Civic Engagements and Responsibilities"—a multidimensional faculty development and curriculum reform program established in 2001 and supported with funds from the US National Science Foundation. SENCER works to improve STEM learning by teaching "through" complex, capacious unsolved matters of civic consequence "to" the canonical STEM disciplinary material deemed essential to a student's education and life-long participation in a democracy. In this chapter, the director and co-founder of the SENCER project provides background and history of the project, articulates project aims and the SENCER ideals, describes SENCER's programs, activities, and the community of practice that SENCER nurtures to bring these ideals to life, and situates the project in the context of emerging challenges for STEM education and democratic practice.

Science Education for New Civic Engagements and Responsibilities (SENCER) is an eight year old faculty development and STEM-education community building program, organized with support from the National Science Foundation. SENCER's core goals are 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' STEM understanding and their capacity for responsible work and citizenship. To achieve these goals, faculty and students design courses and programs and employ effective pedagogical practices and assessment strategies to teach STEM content and methods by focusing on real problems of civic consequence.

The SENCER approach promotes science education that is consistent with the nature of today's students, appeals to their interests, counts on their contributions, and makes science real and relevant to their lives. By their very organization, SENCER courses provide answers to the question: "what do I need this for?" Typically SENCER courses replace standard introductory courses, the academic equivalents of "bridges to nowhere" that Bruce Alberts of the National Academy of Science and Jay Labov of the National Research Council have noted should be called "terminal courses" because they are often both the first and last STEM courses most college students take (*1*).

From design and management perspectives, it is fair to say that the SENCER approach poses different challenges than the textbook driven and "cookbook" lab approach. Like scientific practice itself, organizing and effectively teaching SENCER courses requires extensive "hand crafting" and revision. Because the courses often treat topics that remain "unsolved" and connect learning to emerging conditions and scholarship, they require significant time and labor in their development phase, by students and faculty, alike.

This labor bears fruit. Independent evaluation evidence of SENCER's effectiveness was made possible, in part, because the project had data from the Student Assessment of Learning Gains (SALG) instrument, re-designed and validated as part of the SENCER project. Based on responses by more than 10,000 students, SENCER's independent evaluators, Elaine Seymour and Timothy Weston, reported findings that, at a level of statistical significance, established that students enrolled in SENCER courses—especially female students and those who have traditionally underperformed in science and math—learn more, are able to relate learning to real world problems (including potentially matters affecting employment), are more interested in science after completing the course, and feel more confident in their ability to distinguish between science and pseudo-science. All of these gains—as well as faculty reports on the enhanced learning of scientific content in their courses—are consistent with SENCER's general goal of achieving a national mandate to promote "science for all" and strengthen civic capacity (*2*).

Embracing both new "thematic" approaches to STEM education and progressive pedagogies (including active and inquiry-based learning, interdisciplinary collaborations, academically-based service-learning and community partnerships), the development of SENCER courses requires access to exemplary course materials and curricular "products" as well as connections to other scholars and practitioners who are similarly engaged. Hence, the development of what we call the SENCER community is a vital ingredient in the overall success of the enterprise.

How did we get to where we are today? In this chapter, I will first describe the origins of the SENCER project and identify the contexts in which the project developed. Next, the ideas and ideals of SENCER will be detailed and briefly connected to relevant cognitive theory. Short descriptions of the components of the program will be followed by a concluding note on assessment.

Origins

Last December, my collaborator in the SENCER project, Karen Oates, and I were honored to receive the Bruce Alberts Award for Excellence in Science Education from the American Society for Cell Biology for our SENCER work. At one level, this was an ironic turn of events for me, at least. I had not started what turned out to be my "SENCER journey" with any interest in science learning at all. Indeed my own experience in science and mathematics courses as a student had been pretty unpleasant and not especially successful or rewarding. You could say that I was part of the large cohort of folks who might have preferred having a toothache over an opportunity to enroll in another course in a STEM field.

Back in the 1990's as a member of the administration at Rutgers University I was, however, extremely and urgently concerned about the welfare of our students. So you can easily imagine my great disappointment when I read the report that an independent evaluator had completed for HIV, Biology and Society, a course whose development and delivery by Monica Devanas at Rutgers I had sponsored. (As you will see, for me at least, Monica's course is arguably the original example—the "stem cell," as it were—of something we now call the SENCER approach.)

About the evaluator's findings, I should have known better, but I didn't. Despite the fact that I could have confirmed the contrary from my own experience, the truth is I believed then that having knowledge would lead one to change one's behavior. I had hoped the students who completed Monica's course would have altered their behavior dramatically. Changing behavior—or to be more blunt: encouraging students to adopt consistent and effective personal practices to reduce the spread of a virulent sexually-transmitted disease—had been my reason for providing funds to create a new course in biology that would be focused on the emerging and frightening AIDS epidemic.

Since the evaluation established only modest self-reported changes in reduction of risky behavior, our AIDS course was, at least in the terms by which I was measuring it, surely not a success I had hoped for.

Two decades ago, "AIDS"—and the Human Immunodeficiency Virus that caused it—was a relatively newly-described phenomenon (as pandemic and pathogen) that threatened to involve and infect a whole generation of America's young people between the ages of 18-24. More than half of these young people were enrolled in colleges. From CDC-sponsored sero-prevalence studies in which Rutgers had participated, we knew that the virus was present in some members of our student body (even if we and they didn't know very much about their particular serostatus).

From having administered the CDC's Youth Risk Behavior Survey for college student and from other studies and observations, we also had a pretty good idea of the nature, extent and frequency of behaviors that exposed students to risk. For those of us concerned with the welfare of students, it seemed like it was only a matter of time and chance before what June Osborn (*3*) had famously described as "multidisciplinary trouble" of AIDS could threaten this generation of college students with devastating disease and, in those days before multiple drug therapies and other advances in treatment, almost certain early death.

Given my responsibilities at the time (I had administrative oversight of our student health program, among other things), my main interest was "student life," not improving science education. I had conceptualized and then supported the creation of the "novel" AIDS course where the instructor taught *through* the complex, civic challenge posed by HIV *to* basic biology because, as I said, I thought it might increase awareness and result in changed behavior. It could have saved lives.

At the time, I reasoned that only by using the authority of the curriculum and the scholarship of the instructor and those she could recruit to assist her in delivering the course could we bring understanding the personal and civic dimensions of the issue of HIV from the margins closer to the academic mission of the university. "Dorm talks" by peer educators, bench and other research, and policy review and revision were already part of the University's response to HIV. But inside the curriculum there was a remarkable and stunning silence about a disease that some didn't think it an exaggeration to call "a modern day plague" (*4*).

Initial Lessons

Monica's trailblazing "AIDS course"—as it rather generally came to be known—changed that condition of marginalized silence forever (the course is still taught). We learned that it changed other things, as well.

Since we expected behavior change to be a derivative of general learning, we hadn't included anything specific about behavior change in the course design. You could call this the "magical thinking curriculum mistake." Our experiences in the AIDS course and other subsequent ones have helped me to learn that very little happens magically. <u>You get results on the things you actively teach</u>.

Of special salience for the readers of this book, however, is that we discovered that science learning was improved and even seemed to "stick" longer when that learning was connected to something that is both real and really interesting to students. <u>Relevance matters, at least as an initial intrinsic motivator</u>.

Our students were clearly engaged (a remarkable fact given that the class enrolled more than 400 students at a time). We saw evidence of this engagement in the care and interest with which students completed a particularly challenging and demanding assignment that, among other things, called for their papers to be "peer reviewed" by three other people. Indeed, they had reason to be engaged: some believed that their very lives were at stake. <u>Students respond seriously when they are taken seriously</u>.

From the evaluations and the tests given, we also learned that the biology content had been learned to an impressive degree. We discovered that, in the first year of the course, at least, the science content had been "undertaught"—that encouraged and licensed the instructor to "beef up" the sophistication of the biology content in subsequent iterations. We also learned how to include new dimensions to the course that did focus on behavior to make this curricular approach effective. In short, there were enough positive outcomes from focusing attention on HIV at the course level to recommend generalizing this approach to others.

From a Course to a Program

Beginning in 1994, support from the Centers for Disease Control and the Association of American Colleges and Universities (AAC&U) enabled the creation of a national initiative, the Program for Health and Higher Education (PHHE), to encourage what we subsequently termed "learning for our common health" (*5*). That program spread to scores of colleges and universities and enabled faculty members to create a wide range of courses to bring the issue of public health from the margin closer to the mission of colleges embracing liberal education. Directing the program also enabled me to meet faculty leaders who had focused on HIV and other vexing and emerging health issues to improve learning (and increase students' capacities to be engaged with urgently important civic matters). One of those leaders was the aforementioned Karen Oates, who, as a faculty member and dean at George Mason University, had created not only one of the nation's first AIDS courses but a very successful course that focused on cancer, as well. Karen's acceptance of my invitation to her to join a national leadership advisory committee for PHHE began what has been a most productive partnership.

From Prevention to Pedagogy

A colleague at AAC&U, Rick Weibl, taken by our idea and impressed by the enterprise, enthusiasm and results that campus partners were demonstrating in the courses on HIV that they were creating, suggested to Karen and me that the National Science Foundation would probably be interested in a large-scale project that demonstrated increased learning in the sciences. He pointed us to the then new CCLI "National Dissemination" track. One of the project directors for the new initiative, Myles Boylan, discussed what we were beginning to call "the SENCER idea" with me and invited us to submit a preliminary proposal and then a full proposal somewhat later.

As is often the case, our first proposal fell short of NSF's high expectations. Part of the problem was that we had focused almost our entire proposal on HIV and related public health topics as the compelling "hooks" that would capture student interest and lead to increased learning, most especially in the life sciences. We were asked: Could we show similar learning gains in other fields than life sciences and in other civic challenges beyond emerging diseases?

With NSF support in the form of a planning grant and Karen now serving as a visiting scientist at AAC&U, we spent a year developing the idea, listening to STEM faculty and academic leaders, finding promising course models in physics, conservation biology, and chemistry, and conducting an extensive needs assessment for the work we were proposing. Our subsequent application to NSF to establish the SENCER program met with success and, with NSF's support, we have been expanding and refining the project ever since. (Karen has since left the project and is now a deputy director of the Division on Undergraduate Education at NSF.)

As a program, SENCER began by embracing a set of new and promising pedagogies and explicitly connected them to campus-based aspirations for student learning as well as nationally generated goals for improving STEM education, including the larger context of NRC and NAS recommendations (*6*).

The Larger Context

Ecology theorists argue that "you can never do only one thing" evoking multiple images of unintended consequences, contingency, chaos, and connectedness. In designing the SENCER program we explicitly sought to do more than one thing. Indeed, our efforts were designed to advance two national aspirations and respond to contemporary conditions at the beginning of the 21st century. The aspirations are, first, that all undergraduate students should achieve some proficiency in the STEM fields, especially the sciences and mathematics (*7*, *8*), and second, that students, as citizens in a democracy, be "civically engaged" (*9*). Thus we sought to promote what some have called "science for all" and, by so doing, we hoped to play a part in strengthening our democracy.

Many of the challenges that the National Academies outlined in their reports persist today. Consider where we are: More students than ever before are enrolled in American institutions of higher education. Thus, in theory at least, students have access to education in mathematics and the sciences that is unequaled in quality and unparalleled in scope. Nonetheless, few American students study any more math or science than is required of them. For many students, the STEM study they elect comes as late in their collegiate careers as possible ("the introductory course becomes the terminal course"). Fewer still are the numbers of students completing majors in the STEM fields (*10*).

Of special cause for civic concern, given the conditions just mentioned, is the larger implication for our civic life: Arguably at no other time in our national history have there been more pressing, vexing, and complex civic questions that require STEM knowledge for their understanding (climate change, cap and trade proposals, "rationing" of health care, promoting sustainability, making food and water safe for consumption, making taxation and representation equitable and fair, to name a few). In many other cases (like debates on insurance coverage for medications and sophisticated diagnostic procedures, use of stem cells in research, regulating internet privacy, GMOs, or nanotechnology applications, for example) the civic challenges exist precisely because our advances in STEM have "created" them. They are challenges because we now possess certain scientific knowledge, or technological capacities, or engineering achievements.

These facts have implications for our democracy and our economy. To realize our potential as a "knowledge economy" we need to increase the pool of "achievers" or risk future under-development of our capacities in STEM research and STEM education (*10–13*). The challenge we face is to match our educational assets to contemporary and future needs and to the new generations of students enrolling in higher education. We cannot afford to lose the talent that we are currently not developing among STEM majors—nor among students who are choosing to concentrate their studies in non-STEM fields.

To help meet these challenges, SENCER offers an approach, a set of strategies, a valuable set of curricular and assessment resources, and "membership" in, as well as inspiration from, a community of scholars (faculty, academic leaders, and students) who want to change this situation for the better.

As mentioned, SENCER packages these aspirations and responds to these conditions by helping faculty develop courses that teach "to" science and math "through" the complex, capacious and largely unsolved civic challenges of our day. This engagement helps students acquire scientific knowledge and skills. Building on the successes achieved in individual courses, the SENCER approach is being applied more broadly in major education and general educational reform. The leader of one such comprehensive curricular reform initiative that now embraces some 50 courses, Edward Katz, associate vice chancellor for academic affairs at University of North Carolina—Asheville, and SENCER campus partner, calls SENCER "the nation's most important reform initiative in the area of general and higher education…SENCER provides a foundation for true scientific literacy..." (*14*)

The SENCER Approach to Undergraduate STEM Education

The SENCER approach focuses on real issues of direct interest and relevance to the lives of students and their communities. By so doing, SENCER courses make the case for needing the kinds of knowledge (and knowledge-making strategies/capacities) that the STEM disciplines provide. SENCER courses underscore the relationship of scientific knowledge and scientific methods to the understanding of complex issues or "multidisciplinary troubles."

SENCER respects students as the "novices" they essentially are within the STEM disciplines. But SENCER also respects the assets (the degrees of "expertise" and interests in other matters) that students bring to their studies and that serve them as useful frameworks on which to build scientific and mathematical competencies (*15*, *16*). Because the topics in a typical SENCER course are "larger" than any one field's "content," their study fosters interdisciplinary learning. As Cathy Middlecamp, SENCER Senior Associate and recipient of the 2006 ACS Award for Encouraging Women into Careers in the Chemical Sciences, notes: "by definition we transcend disciplanary boundaries" (*17*). This creates ideal conditions for promoting and testing knowledge transference as described by Eugenia Etkina and Jose Mestre in the SENCER Backgrounder (*18*).

Creating, teaching, refining, and renewing SENCER courses require great ingenuity, energy, and persistence from faculty members, in part because the topics covered are themselves so fluid. They are the very "moving targets" that scientists pursue when they actually do science, so teaching them moves a professor closer to the goal of teaching science as science is actually done

(*19*). To accomplish this new learning, as Larry Cuban has argued, requires new pedagogies (*20*) as well as tried and true (but refreshed) approaches. Thus, a good deal of the SENCER project involves helping faculty (and students) learn new, effective teaching strategies, the power and potential for using of new technologies, and how to improve on traditional approaches. It requires scientists to be scientists about the science of learning (*21*). Faculty developing and teaching SENCER courses report, however, that all the work they had to do to create a text, choose innovative and "hand-crafted" pedagogies and assessment strategies, and keep up with the shifting target (say of childhood obesity, or HIV), is in the end justified because of two things: (1) they were getting to teach something they actually wanted to teach (as opposed to the "watered down" non-majors course) and (2) the students worked harder at the course and learned more.

Above all, SENCER teaches science by modeling what science is: it starts with a real question, something that matters, something of interest to the students and the professor. The SENCER course respects the motives and interests of students and then builds on them, to create genuine learning, learning that "sticks." Since the course topics often represent transnational or multinational challenges, SENCER courses often enrich a campus' portfolio of offerings aimed at "globalizing" learning (*22–24*). Equally, when courses focus on an essentially specific local phenomenon (*25–27*), they contribute to an institution's goal of engaging in a constructive way with local challenges and needs. Ideally and appropriately, given that we are speaking of scientific "facts" which are not bounded geopolitically, the STEM learning gained in one context is readily transferred to many other contexts.

The Intellectual Traditions of SENCER

The essential maneuver in a SENCER course, or learning community, or curriculum is a shift in the "narrative." Beginning with a student's and professor's interests and respecting a student's subject position as standing outside the material to be taught, context is at least provisionally privileged over content. Thus, for example, students enrolled in Professor Barbara Tewksbury's course, "Geology and the Development of Modern Africa," (*28*) at Hamilton are focusing on the political, economic, and social consequences of diamond mining, and, as they are doing so, they are acquiring and using a knowledge of basic geology. It is the depth of study in a particularly capacious and rich topic as that of Dr. Tewksbury's course that begets the breadth desired but rarely achieved in an introductory course that strains to cover everything and ends up uncovering very little.

Putting context (and problems) first has deep intellectual roots in Aristotle, certainly, and in American history in the great "extension education" movement emanating from the Land Grant tradition. In his chapter, "On Interest" from Talks to Teachers (*29*), the American philosopher and pragmatist William James provides us with what we could call the basic organizing rationale for our SENCER's work:

> Can we now formulate any general principle by which the later and more artificial interests connect themselves with these early ones that the child brings with him to the school?
>
> Fortunately, we can: there is a very simple law that relates the acquired and the native interests with each other.
>
> *Any object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. The two associated objects grow, as it were, together: the interesting portion sheds its quality over the whole; and thus things not interesting in their own right borrow an interest which becomes as real and as strong as that of any natively interesting thing.*
>
> The odd circumstance is that the borrowing does not impoverish the source, the objects taken together being more interesting, perhaps, than the originally interesting portion was by itself.
>
> This is one of the most striking proofs of the range of application of the principle of association of ideas in psychology. An idea will infect another with its own emotional interest when they have become both associated together into any sort of a mental total. As there is no limit to the various associations into which an interesting idea may enter, one sees in how many ways an interest may be derived.

As James asserts, "there is no limit to the various associations into which an interesting idea may enter," SENCER accommodates these multiple possibilities not by identifying a narrow range of topics around which SENCER projects may be organized, but instead invites faculty and students to identify which of their interests connect with the canonical course material they hope to teach and learn. Thus, SENCER takes primarily a bottom-up, grass roots approach to creating its community of scholars. The approach often employs teams of professors, or professors and others (representatives from CBOs, government, the community, and, in the best cases, students, as well). Teams are often essential because the material to be learned requires the expertise from different scholars and disciplines. We have also supported a team approach (one that includes academic deans and persons responsible for a college's curriculum) to create more durable institutional change. SENCER seeks to fully engage and employ the intellectual capital of our campus partners in shaping and guiding the work.

SENCER and Democratic Practice

We believe that the approach we've developed embodies a vision of collaborative collective action: materials are shared and regarded as heuristic and instructive (not just someone's private good idea). Our faculty collaborators work to adapt and adopt what they do based on assessment outcomes, peer review, and student interests. SENCER provides the critical social context—a kind of "national glue"—to support the enactment of needed reforms and the "stickiness" (persistence) of those reforms across time.

Since its inception, SENCER has sought to create and nurture a community of "developers" (faculty who craft, teach, and refine courses and programs), as opposed to recruiting a cadre of folks who are implementing a fixed set of components that constitute a "dose" of SENCER. Thus, we have always negotiated a space between orthodoxy, on the one hand, and anarchy, on the other. This seems fitting for a project that aims to support democratic ideals, because a democracy is itself something that occupies a space between these two extremes as well!

Early in the project, we tried to capture the SENCER idea in what we called "The SENCER Ideals"—broad notions that our collaborators could use as "measures" and guides for their own developmental work. We reproduce them here in the SENCER ideals (see below).

The SENCER Ideals

SENCER robustly connects science and civic engagement by teaching "through" complex, contested, capacious, current, and unresolved public issues "to" basic science.

SENCER invites students to put scientific knowledge and scientific method to immediate use on matters of immediate interest to students.

SENCER helps reveal the limits of science by identifying the elements of public issues where science doesn't help us decide what to do.

SENCER shows the power of science by identifying the dimensions of a public issue that can be better understood with certain mathematical and scientific ways of knowing.

SENCER conceives the intellectual project as practical and engaged from the start, as opposed to science education models that view the mind as a kind of "storage shed" where abstract knowledge may be secreted for vague potential uses.

SENCER seeks to extract from the immediate issues, the larger, common lessons about scientific processes and methods.

SENCER locates the responsibility (the burdens and the pleasures) of discovery as the work of the student.

SENCER, by focusing on contested issues, encourages student engagement with "multidisciplinary trouble" and with civic questions that require attention now. By doing so, SENCER hopes to help students overcome both unfounded fears and unquestioning awe of science.

Putting Ideals into Practice

Faculty members who are attracted to the SENCER ideals often find that the biggest challenge they face essentially involves design. Courses that take a traditional approach to "introductory" material in the STEM fields are often textbook-driven. SENCER courses are theme or topic-driven—the civic issue becomes the "text" that helps organize the learning. The challenge is to have the STEM learning align with the narrative elements of the civic question. We use the somewhat pretentious word "capacious," to suggest that the best civic questions around which courses and programs may be developed are the ones that are, in Webster's terms, "able to contain a great deal." They have the morphology to cover (or shadow) and elasticity to "stretch" in such a way so as to facilitate "coverage" of the canonical elements (the basic material) in the discipline that a professor hopes to that students will learn. Some civic questions, to borrow from Walt Whitman, "contain multitudes" (our collaborators, such as those who are using "traffic" as an organizing narrative, for example, often find that their thematic topics contain too much!) (*30*). Other civic questions are tight enough and contained enough to be perfect narratives for teaching a "module" or specific element in a larger STEM course.

Faculty partners developing SENCER courses have found many ways to "design" a SENCER course or program—from highly organized planning teams operating within carefully thought-out schedules all the way to what one collaborator called his "drunkard's walk" (*21*). From the many approaches our partners have narrated, we have abstracted six elements that we can call the components that need to be incorporated in the design of an effective SENCER. They are:

1. **Interests and Motives**—This involves identifying student/faculty interests and motives in order to choose the complex, capacious, unsolved civic issue that will become the "narrative focus" of the course or program.
2. **The Complex, Capacious, Civic Issue (Context)**—This entails cataloging the dimensions of the larger narrative issue (the "complex, capacious, unsolved civic matter," or phenomenon) that will be employed to organize the course or program.
3. **Canonical STEM or Other Disciplinary Elements (Content)**—This involves choosing very specific learning aims and identifying the key learning goals for the course or program, as well as developing a list of the canonical elements in the STEM or other discipline(s) to be taught through the course or program.
4. **Pedagogies**—This entails matching the dimensions of the civic issue to the canonical elements and selecting the particular pedagogical strategies most likely to predict the desired learning outcomes.

(This includes the organization of learning at the "macro" level, such as, is this a course, a set of linked courses, a learning community, a "minor" or special course of study, as well as the particular pedagogies to be used, such as service learning, community-based research, group work, lectures, as well as all texts, exercises, and assessments to be used in the courses and program.)

5. **Action**—This involves identifying the opportunities for practice (rehearsal) and/or action (civic engagement) that the course or program presents and incorporating these in the course or program.
   (Originally we didn't have "action" as a planning dimension, largely because we saw learning as an end in itself and believe that it is up to individuals to decide their own courses of action. That is why we named the project "science education for new civic engagements and responsibilities— "for" as opposed to "by" or "through." Our collaborating students and faculty members, however, have insisted on adding a dimension that at least identifies what one can do with knowledge one has acquired. Beyond that, in referring to "rehearsals" of action, our collaborators see "drafting" letters to public officials, or preparing testimony that could be theoretically delivered to a community board, as examples of effective learning strategies that could be, at the student's discretion, turned into civic actions. For a good description of a fully developed plan to incorporate "action' in the form of community service, see Garon Smith's article (*31*).
6. **Assessment**—This entails designing continuous assessment of the course or program and its learning outcomes and making adjustments based on these assessment findings. The SENCER-SALG instrument (www.salgsite.org) was specifically designed to provide student feedback to instructors from students on which course elements and pedagogical strategies were thought by students to be most effective.

At the center of the design activity is the alignment of the dimensions of the civic question (the parts of that story, as it were) with the key take-away lessons (and skills) in the STEM content area. What makes or breaks this alignment is the choice of the particular pedagogical strategy/technique that is intended to make the intellectual connection and thus increase the effectiveness of the learning. Continuous, close-interval assessment helps determine to what extent this matching process is working. Most serious educators aren't interested in learning after it is too late that what they hoped was being learned wasn't being learned after all. The desire to ensure the learning is actually happening accounts for the rise in SENCER courses of the use of formative "in-class" assessment strategies. These strategies are themselves progressive pedagogical practices.

Models of Good Design

The best way to see how good SENCER courses and programs are designed is to look at the SENCER models. During the first years of the project, we selected about three dozen examples of courses, programs, and learning communities as "models" because they embodied the SENCER approach of teaching "through" a topic of civic consequence "to" the basic STEM content.

Some of these courses were developed by scholars who had never heard of SENCER. These scholars could see how their work embodied our goals and they were happy to share their work with others seeking to improve STEM education. As the SENCER program has developed, more and more courses chosen as models have been the direct products of participation in our project. We are, in the words of one of our South African collaborators, "growing our own timber." With the number of SENCER-supported development projects growing in maturity and with the development of the SENCER digital library (described later), we anticipate that faculty members will have a straightforward opportunity to submit their work for consideration for model status and that our collection of models will grow significantly over the next few years.

SENCER models cover a broad range and diversity in their topics and applications. The course topics cover such complex, capacious civic issues as food security, obesity, diabetes, water quality, emerging diseases, nanotechnology, computer ethics and privacy, nuclear energy and the many dimensions of something as common as sleep deprivation. Those interested in improving quantitative literacy will be interested in the growing collection of models that use civic issues to teach basic and advanced mathematics, including differential equations. At least six of the SENCER models are specifically designed to teach chemistry.

Applications within the SENCER models range from stand-alone courses and course intersections, to linked courses and learning communities, to multi-college collaborations. The models were developed and beta-tested by scholars from all sectors of higher education.

Though the published models contain many valuable resources, such as syllabi, reading lists, simulations, laboratory and fieldwork exercises, assignments, assessments, tests, supplementary materials, and illustrations, the purpose of the models was never to provide ready-made texts that others could simply adopt for their classrooms as some instructors might adopt a textbook or a lab guide. Rather, our purpose in featuring these remarkable models was heuristic: to show the possibilities, the ways to construct courses that embody the SENCER ideals.

A Community of Practice

If there is one thing that I have learned in connection with my work on the SENCER project, it is that educational reform is a socially mediated process. As critical as resources like the models just described are, and they are extremely important, what is essential is to create conditions and "systems" and "structures" that encourage the agents of change—faculty, academic leaders, students, others with interests in science and civic engagement—to be together, to work together, and to reflect on what is being accomplished together. Creating the conditions for a community of practice to develop and flourish is a chief function of our national office and the on-going work of the cadre of senior leaders we have recruited into what some call a "movement" for improving science education, increasing our students' sense of its relevance to their lives, and strengthening our democracy.

Etienne Wenger describes a community of practice succinctly: "Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly." (*32*). This definition is disconnected from the purpose of such a community, thus presumably a street gang that chose to learn together actively could qualify, as could the Vatican's College of Cardinals. The SENCER community of practice doesn't occupy either end of this spectrum, but it does embody the elements Wenger sketches. It is a learning community that relies on its "members" (and those with whom they are connected) for it intellectual capital. The community relies on the SENCER national office to provide the structures, networks, venues, opportunities for connection and dissemination, and other services—such as assessment and evaluation programs—to support the ongoing work of the community.

With its national presence, a seasoned team of leaders, and the benefit of advice and support from a distinguished advisory board, SENCER has an established community-building capacity. On any given challenge or project, SENCER can draw on its large and diverse national community of more than 1,500 scholars from 350 institutions in 46 states and several foreign nations, as well as collaborators from the informal science education community and other governmental and non-governmental organizations.

Supporting the SENCER Community of Practice

It seems a bit silly in the Internet age to use printed text to list in any great detail SENCER's program components and the resources available to the STEM education and larger community, but it does make sense in a chapter designed to orient readers to the project to sketch broad categories of our program activities and give brief examples of the program elements in each. Readers are invited to access and use these resources either through the website, www.sencer.net, or by contacting the SENCER national office.

Professional Development: Institutes, Symposia, Regional Centers for Innovation *Three of SENCER's projects aimed at creating a community of practice through professional development are highlighted in this section:*

SENCER Summer Institutes are annual, invitational, intensive professional development programs. They are designed to be times for reflection and accomplishment by faculty, academic leaders, and, students working to achieve goals for improved learning though course design or redesign. The Institutes facilitate project development by providing uninterrupted work time for teams, connections to peers from around the country, and opportunities for immediate consultations with experts in course design. The Institutes draw an intensely multidisciplinary group of participants representing all higher education sectors, schools districts, government, non-government organizations, and educational/professional associations. Institutes are hosted on campus by colleges and universities with special involvement with SENCER.

Summer Institute attendees learn about new pedagogies and assessment techniques, share results of implementations, and discuss ongoing research in the science of learning. First-time participants are introduced to a network of returning alumni and experts in the learning sciences and innovative pedagogies who mentor new teams and offer in-formal consultation in the time following participation in a Summer Institute.

Washington Symposium and Capitol Hill Poster Session SENCER and the National Center for Science and Civic Engagement host an annual Washington Symposium and Capitol Hill Poster Session that gathers educators, students, and policy makers to address questions of student learning in the sciences, technology, engineering, and mathematics on a local and national level. Specifically designed for members of the SENCER community with mature projects, the Symposium provides opportunities for participants to present their campus-based work to members of Congress, their staffs, and the general public. Students, who traditionally compose more than one-third of the attendees, represent their own experiences as scholars in SENCER courses and as contributors to the development of new courses.

In addition to sharing their work during a poster session and meetings on Capitol Hill, students and educators participate in work sessions on cross-cutting issues and new challenges. SENCER especially seeks to include representatives of organizations other than schools, colleges, and universities in discussions on policy and collaborative efforts to improve courses. Organizations including the National Oceanic and Atmospheric Administration and the National Geographic Society have participated discussions on how educators, non-profit groups, and government agencies can coordinate to address civic questions and give students a broader view of how science, technology, engineering, and mathematics operate in the world using the vast reserves of real-time data.

The SENCER Centers for Innovation (SCI) provide strong regional networks, supporting 'alumni' and those new to SENCER. The SCIs—New England, West, Midwest, Mid-Atlantic, and South—are designed to fulfill the needs of the community on a local level and to offer symposia and workshops that complement national activities. The Centers are multi-institutional groups with a common commitment to improving the quality of STEM teaching and learning by using the SENCER approach. They conduct at least two workshops or symposia per year, provide local experts for on-campus consultations, plan regional projects, and offer guidance on the development of new courses and programs. Each Center for Innovation is guided by two co-directors and a Leadership Council, whose members represent institutions in the regional area.

Documentation and Dissemination: Models, Journal, Consultations and House Calls, E-News

SENCER was originally described as a national dissemination project and dissemination remains a key dimension of our work and a critical element in community building. Just as the Summer Institute could be called the "centerpiece" of our professional development program, the SENCER models, described earlier in this chapter, could be regarded as the centerpiece of our dissemination and documentation efforts. Three other documentation and dissemination and dissemination initiatives will be mentioned here.

Science Education and Civic Engagement: an International Journal is a peer-reviewed, web-based journal that focuses on using unsolved, complex civic issues as a framework to develop students' understanding of the role of scientific knowledge in personal and public decision making. The full text of issues of the Journal and guidelines for prospective authors are available at www.seceij.net.

Consultations and House Calls SENCER supports members of the academic community by providing expert assistance for course and curricular innovations. Often this is accomplished though telephone consultation, providing referrals to faculty and academic leaders who can help, reviewing materials, and providing feedback on drafts of curricular, grant applications, and other proposals. Sometimes, however, campus personnel conclude that a personal visit—a "house call"—by someone with direct experience and knowledge of SENCER is what is really needed. The SENCER national office staff is helps arrange house calls. In the past, leaders in the SENCER community have helped faculty and administrators with faculty development, large-scale curriculum reform, introductory and STEM majors courses, the development of topical courses (e.g. health, environment), and the infusion of civic engagement into existing courses.

Virtual Community: Website, e-News SENCER maintains a vibrant website at www.sencer.net that provides all visitors access to the full text of the SENCER Model Series and backgrounders, a variety of assessment tools, information and applications for national and regional symposia, best practices/campus reports, job opportunities, grant announcements, and press releases. Anyone interested in SENCER is invited to sign up to receive the biweekly SENCER e-News to stay current on new opportunities and tools to improve STEM education, as well as to maintain connections with the SENCER community.

Distributed Leadership: Leadership Fellows, Awards

SENCER has adopted a distributed leadership approach within our community of practice. A small group of paid staff and scholars is supplemented by a larger group of senior associates, senior fellows, visiting scientists and mathematicians, and others. Our work is also distributed in that innovation and inventions are campus-based, generally localized in specific projects that the SENCER national office is supporting with NSF implementation sub-awards. We also take seriously our obligation to support the members of our community of practice with letters connected to promotion and tenure, support for intramural and extramural funding opportunities, and, recognition in our publications and at our meetings. In this section we describe briefly our leadership fellows program, our sub-award program and the new award we have named in honor one of our most influential; leaders, William E. Bennett.

Leadership Fellows The SENCER Leadership Fellows Program offers SENCER "alumni" the opportunity for greater involvement in the SENCER initiative and affords the National Center Science and Civic Engagement opportunities to recognize the hard work and significant accomplishments of those who have developed strong programs on campus.

Fellows help guide the SENCER project by participating in annual meetings of the Leadership Fellows Council. They develop and carry out projects that extend the reach and deepen the impact of the SENCER program on their campuses, in their disciplines, and in their communities. They report their progress using an interactive database. As noted, fellows participate in regional initiatives through their affiliations with the SENCER Center for Innovation of their choice. Fellows serve 18-month terms and identify specific activities that will become the foci of their Fellowship term. Applications and nominations for election to the Leadership Fellows Program are welcomed at any time. Decisions on the applications are made semi-annually by National Fellowship Board, a group of distinguished educational leaders and scholars. As of this writing, 85 academic leaders have been elected as fellows.

SENCER-NSF Post-Institute Implementation Awards SENCER annually awards NSF-supported sub-grants to institutions that have sponsored team attendance at a SENCER Summer Institute and that successfully complete a competitive application process. Grants—modest in scale but often bold in effect—are awarded for two-year terms to support projects such as course/curriculum designs or re-designs, faculty development efforts, and inter-institutional partnerships. Since the inception of the project, SENCER has made more than 200 sub-awards to colleges and universities for team-based projects. As a result, hundreds of courses have been launched or re-designed.

Several former awardees have been able to use the sub-awards as "pilot projects" and have subsequently leveraged their results to garner major funding from their own institutions, foundations, and government organizations, such as the National Science Foundation and the National Institutes of Health. These funds have been used for program expansion, refinement, and to scale up projects to impact more students and communities.

The William E. Bennett Award for Extraordinary Contributions to Citizen Science was established in 2009 to honor extraordinary contributions to citizen science, as understood broadly within the SENCER context. The award celebrates the career and post-career work of Bill Bennett, scientist, educator, science administrator, and former senior science advisor to the Secretary, U.S. Department of Health and Human Services. Bill has been a senior scholar for SENCER and the National Center for Science and Civic Engagement since our beginnings.

The Bennett award will be made annually to a person (or persons) for extraordinary achievements in fostering students' capacities to engage in science, technology, engineering and mathematics and to apply their knowledge, skills and energies to an issue of civic consequence.

Resources: Backgrounders, Digital Library, and Assessment Materials and Services

To support the SENCER community, we have made significant investments in providing useful materials (like the models, described earlier) as well as briefing papers, called backgrounders, and we have organized materials produced in the project into a readily accessible, searchable digital library. A common commitment to assessment has also led to the development of assessment tools and resources. These resources provide yet another opportunity for those affiliated with SENCER to act as a community of practice, contributing materials to the assessment effort and using the assessment database to improve their own pedagogical practices and course design. This section highlights three dimensions of this area of our work—an area that is directly aimed at contributing to what the National Science Foundation has termed the "STEM education knowledge base."

SENCER Backgrounders are commissioned papers in which scholars explore the wider range of issues that link science and complex civic challenges. The backgrounders identify opportunities to use the best learning research we have to increase the likelihood that a course or program will achieve its intended goals. Topical backgrounders provide intelligent, general readers with high quality syntheses of the complex, civic issues. Papers added to the series are published on the SENCER website and currently cover topics including hunger and public policy, the human genome project, nanotechnology, and biological diversity. Backgrounders have also been commissioned on cognitive science and science learning for non-majors, SENCER and quantitative literacy, the pedagogy of service learning, faculty transformation and institutional change. Backgrounders are generally presented in draft form at our Summer Institutes and subsequently revised for publication and inclusion in the digital library.

The SENCER Digital Library Launched in 2008, the Library houses the growing collection of courses and programs in the model series, SENCER backgrounders, short essays, e-News articles, course materials, and other materials being produced by the SENCER project and our campus partners. The Library allows visitors to easily perform advanced searches on all SENCER resources. Searches can be customized by learning strategy, assessment tool, civic issue, or subject discipline. The Library was constructed in a collaborative effort that involved leaders of the Science Education Research Center (SERC) at Carleton College, students and faculty from the School of Information and Library Sciences at Rutgers University, and SENCER staff.

The Digital Library, which is hosted at SERC, can be accessed freely by using the search features on every menu on the SENCER Web site.

Assessment Resources SENCER has adopted, commissioned and supported the development of a suite of assessment tools and resources. Assessment activities are coordinated by our national director of assessment and evaluation, who is supported by an assessment advisory group. SENCER's assessment interests and programs include initiatives in formative assessment, rubric development and validation, and learning research. The three major components of the SENCER assessment effort—the SENCER-SALG, SENCER-SoTL (affiliated with the Carnegie Foundation's Scholarship of Teaching and Learning effort, campus-based and faculty/student led research projects on matters of interest to the SENCER community), and CASA (Committee on Assessment for Student Achievement, a volunteer group focused on developing a large collection of formative assessment strategies for a broad range of SENCER applications). We will discuss the SALG in brief detail here.

The SENCER Student Assessment of Learning Gains (SENCER-SALG) is an online tool that promotes meta-cognitive thinking in students by encouraging them to rate how specific activities in SENCER courses help their learning. Students report on their general level of science skills and interests, as well as the civic activities in which they engage. The primary purpose of the SALG is to provide useful, formative feedback to instructors interested in improving their teaching. Students rate how much class activities such as lectures, discussions, or labs help their learning. The SALG also provides a snapshot of student skills and confidence at the beginning and end of courses, allowing instructors to gauge the effectiveness of their instruction in specific areas.

The SALG, which was developed in collaboration with the SENCER project, is a free service open to all faculty members, whether involved with SENCER or not. It is now maintained by the University of Wisconsin-Madison with support the National Science Foundation.

The aggregated results of individual SENCER SALG implementations inform the national assessment of the SENCER program. All faculty affiliated with SENCER are encouraged to use the SALG and all SENCER sub-awardees are required to use the instrument in connection with their course implementation projects. Thus SENCER has access to a large database to be used for evaluation and program improvement purposes. More information can be found at http://salgsite.org.

Future Plans

As noted, SENCER supports an expanding community of learners and scholars—students, faculty, educators, academic leaders, and representatives from both governmental and non-governmental organizations—who share a commitment to improving learning and building civic capacity. Since the SENCER program counts on its members to contribute to the intellectual capital of the project by producing knowledge and sharing insights, resources, and assessments with one another, and since we are committed to promoting democratic practice, we can never know exactly where our collaborations will lead. We do know, however, that we are now poised to take what has been learned in the project so far and put it in the service of critical national goals for improved STEM learning, workforce development, and the public good.

Cross-cutting issues that animate dimensions of SENCER's current and future work include: (1) increasing the level of science and mathematics learning achieved in SENCER courses and connecting this knowledge to workforce challenges, specifically to new careers that will depend on greater capacity in the STEM areas and abilities and dispositions developed through inquiry based practices (2) using the SENCER approach to attract more students to pre-service teacher education (especially at the elementary school level) and exploring the feasibility of developing primary and secondary school

SENCER courses and curricular projects in college-level courses, (3) extending the SENCER approach to the education of STEM majors, (4) using the diverse SENCER community to strengthen connections between community and four year colleges, and (5) exploring communities of interest among those working in formal and informal science education.

Democracy and science share many common traits, as scholars have long noted. At their best and in what some readers will recognize as an ideal world, both offer methods for discernment, not oracular revelations of immutable and private truths. Both deal in the tentative and the provisional—what we do today may be different from what we do tomorrow when we have better information. Both are social practices, with all the good and bad things that go with social practices. Both do their business in public and hold what they do up to public scrutiny. Both follow agreed upon rules for guaranteeing integrity in their processes and some degree of reliability in their results. Both require hard work. Both lead to places we can not always predict.

The great historian, Bill Cronon, once said of liberal learning—learning for human freedom—that we can never know where the bridges that we build for students will lead them, but we do know that it is our obligation to build bridges that are supple and strong enough—he used the word "capacious"—to help them get where they want to go (*33*). We've tried to build SENCER as that kind of bridge, between science and non-science, between disciplines, among scholars and students. We are grateful to those who are lending their efforts in its construction—you'll hear from some of them in this book. We invite you, the reader, to connect with SENCER in ways that will prove mutually productive as we apply the science of learning to the learning of science, all in the service of building a stronger democracy for all.

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Chapter 2

The SENCER Models

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This essay traces the evolution of the SENCER Model series from the beginning of the project in 2001 to the present. It describes the criteria used to identify model courses and programs, changes in format and presentation, and the role the models have played in both supporting and shaping this national dissemination project. It concludes by suggesting that emerging trends in SENCER model courses and programs and programs over the last decade point to encouraging new directions in STEM education.

The SENCER models are a key element of the program's dissemination strategy. They were originally conceived of as a defined group of field-tested courses and programs selected as exemplary, not only of the "SENCER Ideals," but of the educational standards and principles recommended by others with a stake in improving education, including the American Association for the Advancement of Science and the National Research Council. By definition SENCER models are curricular approaches that improve science learning while supporting engagement with complex issues. Through the "lens" of a problem of public consequence, a SENCER model teaches science that is both challenging and rigorous, requiring students to engage in serious scientific reasoning, inquiry, observation, and measurement. Courses selected as models of the SENCER approach connect scientific knowledge to public decision-making, policy development, and the effective "work" of citizenship while they encourage students to engage in research, to produce knowledge, to develop answers, while appreciating the provisional nature of the knowledge and answers produced. To be considered for selection as a SENCER model, the course or program incorporates strong assessment techniques that allow rolling evaluation and adjustments, based on student learning and student needs. Most of the models selected within the last three years have employed the SENCER "SALG" (Student Assessment of Learning Gains) instrument, which was developed as part of SENCER to assess the impact of courses on a full range of both science and non-science learning outcomes.

Selected models are published electronically on the SENCER website (www.sencer.net) where they are among the most-often accessed resources. Since 2001 over three dozen models have been featured and disseminated electronically and that number will continue to grow as the SENCER approach is adopted by faculties and departments seeking to improve science education in their colleges or universities. For those of us who have been with the project from the beginning, our understanding of how these models are used, what they are models of, and how STEM education reform is actually taking place on our campuses has been both challenged and clarified by the evolution of the SENCER model series over the last four years. This essay will attempt to trace that evolution by describing the history of the model series, and then point to some new directions and developments, not only in SENCER models, but in STEM education in general.

Models of What?

In its dictionary definition, a model is "an example for imitation or emulation" and SENCER's origins as a national project began with a single example, the course "Biomedical Issues of HIV/AIDS," which was designed and taught by Dr. Monica Devanas at Rutgers University. This course for non-majors teaches the biology of infectious diseases, immunology, and virology through the questions that surround HIV/AIDS: Where did it come from? How is it transmitted? Can I get it? What can we do to help those that have it? These driving questions motivate students to learn complex scientific content in microbiology and immunology but they also reveal that these questions cannot be answered solely by an appeal to biology, as they are also impacted by economics, politics, education, and human emotion and psychology.

Beyond being a model of innovation in the delivery of science content, "Biomedical Issues of HIV/AIDS" is a model of creative pedagogy. Despite being a very large (400+) lecture course, it emphasizes active learning and critical thinking through online discussion groups, guest lectures, and research and writing-intensive assignments. It uses student interest as a spur to learning by allowing participants to select a compelling problem and specific population and asks them to investigate clinical studies and design an educational intervention. By negotiating library databases, collecting peer-reviewed primary research articles, and using these articles and statistics to support their own ideas, students develop proposals for improving the HIV/AIDS crisis in their target group. They are then asked to have friends, family members, and colleagues read and comment on their proposals, as well as one professional with special expertise on some medical, social, or cultural aspect of HIV/AIDS.

In the course of their research, students work hard to uncover the relationships between scientific and medical research and political agendas. They work even harder to find information about how their career choices are impacted by HIV/AIDS; how their projects and studies may help fight risky behaviors in target communities; how to grapple with the questions of AIDS in the workplace; how cultural influences work to obscure and repress acknowledgement of actual sexual behavior. Students in this course have shown an eagerness to engage their new knowledge and seek forums for discussions where they can debate issues and ask critical questions. Expert guest lecturers, many of whom are HIV-positive themselves, bring the reality and immediacy of living with HIV/AIDS to the classroom, helping the students to better understand the connection between their academic learning and everyday life.

"Biomedical Issues of HIV/AIDS" embodied all of the elements that were formalized as the "SENCER Ideals" and became the criteria used to evaluate and select courses and programs for inclusion in the model series. A SENCER model was expected to:

- robustly connect science and civic engagement by teaching "through" complex, contested, capacious, current, and unresolved public issues "to" basic science.
- invite students to put scientific knowledge and scientific method to immediate use on matters of immediate interest to students.
- reveal the limits of science by identifying the elements of public issues where science doesn't help us decide what to do.
- show the power of science by identifying the dimensions of a public issue that can be better understood with certain mathematical and scientific ways of knowing.
- conceive of the intellectual project as practical and engaged from the start,
- as opposed to science education models that view the mind as a kind of "storage shed."
- extract from the immediate issues, the larger, common lessons about scientific processes and methods.
- locate the responsibility (the burdens and the pleasures) of discovery as the work of the student.
- encourage student engagement with "multidisciplinary trouble" and with civic questions that require attention now.
- help students overcome both unfounded fears and unquestioning awe of science.

The popularity and effectiveness of this course, not only in engaging non-majors in rigorous science learning by appealing to their existing interests and concerns, but also in fostering so many of the practices, attitudes and dispositions of a liberally educated individual, was the starting point for the national initiative we now call SENCER. The story of its evolution from the original "model" of "Biomedical Issues of HIV/AIDS" has been described by fully and eloquently by David Burns in the article "Knowledge to Make our Democracy." (*Liberal Education*, Fall, 2002).

With these ideals as a starting point, it could be predicted that SENCER models would be examples of much more than an approach to content. In fact, the deliberately inter-and trans-disciplinary assumptions of SENCER courses, and the fact that they engaged *unsolved civic* problems, almost guaranteed that innovative and non-traditional pedagogies and curricular formats—specifically those that directly engaged students in problem solving and inquiry-based active learning—would be employed. As predicted, SENCER models drew on a remarkable range of creative teaching strategies and every possible format, from compressed video to small seminars, from large lectures to field-based research courses.

The SENCER Approach to Dissemination

While SENCER was initiated in 2001 under the National Science Foundation's CCLI national dissemination track it differed from the typical dissemination project in significant ways. There was no single method, technique, or content being disseminated as part of a "top down" approach to innovation. Instead, what was being disseminated was a strategy, or a way of thinking about, science education that could be adapted for use in the widest range of institutional and educational contexts. Consequently, the original idea behind the models was not to design or create a set of paradigmatic SENCER courses and disseminate them, but to select from a nominated pool of already existing courses that exemplified this strategy as a way of demonstrating that the SENCER approach was not a new and untested idea, but an approach to learning that was being used successfully by innovative faculty in colleges and universities throughout the country. SENCER, therefore, became a way of organizing, linking, and expanding—assigning a name to—an approach to learning that was already succeeding, often in isolated pockets of innovation, around the country.

It is important to reiterate here that the commitment to highlighting existing courses in specific colleges and universities, despite their unique and non-transferable attributes, was central to the project's design. The SENCER models were never intended for wholesale adoption and implementation by others, rather they were offered for their heuristic value—as spurs to innovation and inspiration and as examples of what was possible and what worked. Perhaps even more importantly, the SENCER model series was created to offer national recognition to faculty innovators, validating their efforts and increasing their effectiveness as advocates and voices for change on their home campuses. What was being disseminated in SENCER was not a single, "one-size-fits-all" idea or technique, but success stories of courses and programs that were improving both science education AND civic engagement by exploring the inextricability of science and policy in our contemporary culture.

The Evolution of the Models

The original decision to feature and disseminate model "courses," rather than larger institutional initiatives, was a conscious one. Although the overall

SENCER national strategy was designed to foster systemic and sustained reform and not simply local and unsystemic improvements in STEM education, it was still assumed that discrete courses, and the individual faculty who created and taught them, would be the essential building blocks of any larger movement to improve science education.

Organization

The first significant development in the model series was the adoption of the "course portfolio" format. In year one the presentational format of the SENCER models placed a heavy emphasis on the degree to which the selected course exemplified, not only specific "SENCER Ideals," but national goals and standards, including those that had been developed for science education by the American Association for the Advancement of Science, and for the improvement of teaching in general by the American Psychological Association (For an example, see "Chemistry and the Environment," taught at Santa Clara University by Professor Amy Shachter, http://www.sencer.net/models.cfm) This decision was grounded in the assumption that making the case for SENCER involved addressing a national audience of educational experts who would require evidence that such courses could meet and exceed the most rigorous national, research-based standards for content, pedagogy, and assessment. It became clear by the second year of the project, however, that while such an approach had validity, it did not fully address the concerns and interests of an even more important audience that would be key to the success of the project: the departmental faculty and administrators who were concerned about whether SENCER courses would meet the specific curricular needs and undergraduate learning goals of their individual institutions. In response to feedback we collected during the first year, the model presentation format was changed to mirror the framework and categories of a typical faculty "course portfolio." This has meant that the model authors were asked to reflect in greater detail on the relationship of their course to the overall curriculum, the general education program, and other academic goals and priorities at their specific colleges and universities. The hope was that such a framing would not only better address the key concerns of skeptics on campuses, but that it would also "model" a strategy of course presentation that faculty could use to make the strongest possible case for the value of their work to their institutions. This format, with minor modifications, has remained in place since year two of the project.

Content

From the beginning, courses in interdisciplinary science, technology, and engineering were actively solicited. However, given the ubiquitous organization of colleges and universities into discipline-based departments, there was an expectation that most of the courses nominated, as well as the faculty teaching them, would fall into the traditional STEM disciplines—biology, chemistry, physics, mathematics—and that a balance among these disciplines would be a key criteria in selecting courses for inclusion. But despite the expectation of disciplinarity, by the fourth year of the project it was clear that explicitly inter- and multidisciplinary science courses—particularly those addressing environmental and health topics—were becoming more commonplace in the non-majors science curriculum. While we were still offering SENCER models in single disciplines like Biology (Franklin & Marshall's "Tuberculosis"), or Chemistry (University of Wisconsin's "Chemistry and Ethnicity"), an increasing number of models were either introductions to explicitly interdisciplinary science fields (such as geosciences, environmental science, nutrition, forensics, cryptography) or they invoked science content in various disciplines in the context of particular civic problems, as in the case of Fairmont State's "Coal in the Heart of Appalachia," (geology, chemistry, physics), and Bard College's "Environment and Disease" (chemistry, biology, mathematics).

Pedagogy

Certain pedagogical trends were also emerging. By year five, nine of the nineteen models were team taught, involving faculty in all of the science disciplines as well as political scientists, psychologists, literary scholars, social workers, and historians, reflecting a greater willingness on the part of institutions to support cross-disciplinary inquiry. It was also becoming clear that in addition to improving science learning, SENCER courses were supporting a broad range of institutional goals and objectives, including engaged and experiential learning, civic engagement, internationalization of the curriculum, and undergraduate research. Consequently, SENCER strategies were often found embedded in, or attached to, institutionally supported pockets of innovation designed to support those goals, including learning communities, service-learning and community-based learning programs, course intersections, writing intensive courses, and first-year seminars, to name a few.

"Growing Your Own"

It became increasingly clear from the SENCER programs that were developed by faculty participating in the first five Summer Institutes that discrete courses alone are not the only "containers" where a new approach to science education could be cultivated. Often the "SENCER" component (eg. the linking of the science content and the civic questions) resided not in a course, per se, but in an intersection or pairing of courses (as in Vassar's "Chemistry and Policy") or in the integration of content from two modules built into a learning community (as in Wagner's "Sustainability and Human Health.").

As has been the case with the entire SENCER project over the past four years, it will be the "members," as we like to call the hundreds of faculty, administrators, and students who have been involved in the SENCER project thus far, who will guide the direction and evolution of the model series. The number and quality of submissions has already resulted in an increase in the number of models offered each year (from four in 2001 to seven in 2008). We are particularly proud that since 2004 the majority of models have been courses or programs developed from work begun at the Summer Institutes. Last year's additions to the model series reflects the creative ways that faculty have invoked and embedded the SENCER ideals into their curriculum designs, and are indicative of how the model series has evolved from its original conceptualization. This diverse group of resources includes international collaborations, single courses, and course clusters, and take up such compelling issues as sleep deprivation, HIV/AIDS in Africa, food security, and pregnancy outcomes.

Format

Because SENCER is a dissemination project the question of how to best present and "publish" the models has been an important one. In the first two years the models were distributed at the Summer Institutes in spiral bound paper copies as well as electronically on CD-ROM as PDF files. It seems hard to believe now, but in 2001 many individuals, and even entire teams, arrived at the Institute without laptops, so print was still an important component of dissemination within the project. By year four the number of models had grown to the point that distributing paper copies was no longer feasible and the models were delivered exclusively through electronic media, with PDF files of each model distributed on CD-ROM and uploaded to the web.

There were advantages to "publishing" the models as PDF's, including the relative simplicity of translating a variety of materials (including photos, diagrams, tables etc) into a unified and consistent format, and its readability by any operating system. But as the series grew (from an original four to thirty-seven models in 2008), the disadvantages of the PDF format became more apparent. Embedded links would often not survive as documents were uploaded to the web or burned on CD's. More problematic was the sheer quantity of information contained in each document and the difficulty of searching for specific information or key words without printing out an entire document, which was both wasteful and time-consuming. While the civic question and/or discipline addressed by the course was typically clear from titles, the chronological presentation and lack of a user-friendly search engine made it hard for interested faculty to quickly identify and locate other features of the models that were relevant to their own practice, whether it be pedagogical approaches, assessment strategies, or course content and organization.

The SENCER Digital Library

It became clear a few years ago that if the model series was to continue to grow, the material would have to be made searchable and converted to HTML. This past year the models underwent their next major evolution with the launch of the SENCER Digital Library, a system that allows users to access all SENCER resources on the web through a searchable database. The Library houses the growing collection of courses and programs in the model series, SENCER backgrounders, and will soon encompass articles from the e-Newsletter, course materials, and short essays.

In the new Digital Library format users are no longer restricted to viewing or downloading the model as a static PDF document. Rather each model has been translated into HTML and broken down into sections that may be accessed by clicking on the navigation bar on the webpage for each model. Visitors can now easily sort by and navigate the information they are most interested in, including the course background, activities, the civic issues addressed, assessment methods and analysis, and relevant citations. The new format will make it possible for faculty to update their models easily, allowing interested users to track the evolution of courses and programs over time and learn from that progress.

Creating the SENCER Digital Library was a lengthy and complex process made possible by an exciting collaborative effort involving the work of teams from Carleton College and Rutgers University, with input from SENCER staff, and coordination by Chuck Gahun. The Library is hosted by the Science Education Resource Center (SERC) at Carleton College, and uses their content management abilities to support searching of all materials. SERC supports educators in a broad range of disciplines by coordinating faculty development workshops, by continuing to develop their extensive web resources, and by engaging in research and evaluation of how faculty use the web in teaching. Cathy Manduca and Sean Fox of SERC consulted with SENCER since the beginning of the project and were able to customize a web-based presentation system that retained the effective elements of the existing format while creating a flexible structure that would streamline the selection, editing, formatting, and publishing of the models.

Once the new web format was designed, the existing materials had to be re-organized, reformatted and digitized. The team from Rutgers University, led by Claire McInerney, identified controlled vocabularies for all the resources, defined content categories, and entered the content and metadata into the new system. The Rutgers team included graduate students Krista White and Sarah Legins and undergraduates Kerri Hueftle and Melody Townley. To launch the new Library, Krista, Kerri, and Melody attended SSI 2008 and presented both a poster and a session on the development of the project and the creation of the metadata.

The launch of the SENCER Digital Library opens new prospects for the model series. Currently a web interface is being developed that will allow faculty whose courses meet the SENCER model criteria to enter their submissions directly to the web, eliminating the editing, reformatting, and uploading involved in producing the PDF files. We anticipate that new models will be added on a rolling basis (rather than on an annual deadline geared to launching new models at the Summer Institute).

Trends and Challenges

As noted above, SENCER has evolved to the point that the vast majority of featured models could be selected from courses and programs developed by faculty and administrators who have participated in the SENCER Institute. Since most teams come to the Summer Institute with the goal of creating courses and programs that address specific curricular goals and problems facing their institutions, the models could be seen as reflecting certain emerging trends in undergraduate STEM education. One of the clearest trends is a heightened concern with quantitative literacy and a growing appreciation of the advantages of SENCER strategies in engaging students in mathematics and statistics. In the first three years of the project there was only one SENCER model in mathematics (Spellman's "Chance.) Today there are five courses, including one upper division course (Rutgers's "Mathematics of Communication).

Although SENCER was conceived as an initiative focused on improving science for non-majors through the general education curriculum, there has been a growth in the adoption of SENCER strategies in upper division courses and courses that contribute to majors. Some of these include Southern Connecticut State's "Computer Ethics," Bryn Mawr's "Ordinary Differential Equations," and Franklin & Marshall's "Public Health Research." A scan of recently nominated models suggests that there will be a significant growth in the number of upper-division and major's courses using SENCER strategies in the future. There is also a noticeable trend in the use of SENCER strategies in professional education tracks, specifically pre-service teacher training (Hampton's "Riverscape,") and nursing (Kent State's "Human Genetics.")

While these trends are very encouraging, there are some areas where there has been less innovation and progress than anticipated. Despite the fact that topics in engineering are inextricable from civic and social contexts, we have yet to have an engineering model. Topics relating to technology are slightly more common, with two computer science models and one in nanotechnology. In the traditional science disciplines, physics continues to be under-represented, though it is a component of interdisciplinary science courses such as "Science, Society, and Global Catastrophes," and "Forensics." On a more positive note, is clear trend visible in the extension of SENCER models to courses in the social sciences. A substantial number of SENCER models are already team-taught with social science faculty in economics, psychology, sociology, political science and other fields, and a model series of SENCER courses in these disciplines is under discussion.

As the model series enters its ninth year, SENCER continues to encourage and solicit models that exemplify the founding ideals, knowing that innovative faculty will continue to take the project in new directions that were undreamed of a decade ago. SENCER models are now ready to move beyond the traditional undergraduate course. Course modules, entire curricular programs, k-12 courses, pre-professional and graduate education, are all possible areas of development, and we eagerly look forward to the next decade of growth and evolution.

Returning to the question "models of what?," with almost a decade of hindsight we can now see that the SENCER models are examples of rigorous, inquiry based science education, of innovative and engaged pedagogies, and most importantly, of faculty-led curricular improvement and reform. From years of testimonials by participants, we now know that SENCER models are records of faculty and student transformation and invigoration and examples of democratic educational practice , reminding us all that the attention we give to our complex, unsolved, civic questions, and to the role that science will play in their resolution, will determine our common future.

Chapter 3

SENCER at TWU

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Since the summer of 2007, the faculty at Texas Woman's University has embraced the ideals of SENCER and has worked diligently to incorporate those ideals in the classes they teach. Further, new courses which contain civic engagement components have been developed or are in the planning stages. This chapter demonstrates the facility of incorporating SENCER into courses and programs of study. In addition, efforts to get the good word about SENCER out to other science educators are discussed. Finally, plans for keeping the momentum going are presented and include a new, innovative certificate program titled Science and Civic Engagement.

Introduction

Texas Woman's University is the largest public university primarily for women in the United States with an enrollment of approximately 13400 students at three campuses: Denton, Dallas and Houston. The university offers a wide range of BS, BA, MS, MA, and PhD degree programs in the liberal arts, natural sciences and mathematics, health sciences, nursing and education. Most BS degrees require a minimum of 120 semester credit hours. Regardless of degree program, all baccalaureate students must satisfy a core curriculum requirement of 42 credits which includes at least six credits of natural science courses with laboratory and six hours of courses designated as global perspectives courses. Recently, the University has developed three initiatives which constitute a basis for our institutional focus: 1) Women in Business; 2) Health and Wellness; and 3) Globalization. Hence, the university has an intellectual environment perfect for the introduction of the SENCER ideals, discussed in the first chapter of this book, into our curricula.

The Department of Chemistry and Physics, an academic unit within the College of Arts and Sciences, has taken a leadership role in infusing of SENCER goals into our campus. What follows is a description of where we are now and where we want to be in the next few years. This chapter demonstrates the facility of incorporating civic engagement into our courses and programs.

SENCER Courses at TWU

The Department of Chemistry and Physics at TWU offers several courses that are approved as natural science and global perspectives core courses. These offerings include courses in chemistry (CHEM), physics (PHYS) and science (SCI) for both science and non-science majors. Approval of any course for fulfilling a core requirement is based on satisfying Exemplary Educational Objectives. The university, as well as the state of Texas, has a specified set of expectations for core science courses and for the global perspectives credit.

Global Knowledge and Perspectives Educational Objectives

1. Demonstrate the awareness that one has a view of the world that is not universally shared, that there is a distinction between opinion and perspective.
2. Demonstrate understanding of cultural/civilization complexities that can alter the interpretation of world events.
3. Demonstrate understanding of prevailing world conditions, developments and trends associated with world issues such as population growth, economic conditions, and inter-nation conflicts.
4. Demonstrate the knowledge, values and skills needed to participate in decisions about the way we do things individually and collectively, both locally and globally that improve the quality of life now without damaging the planet for the future.
5. Demonstrate knowledge of one's own political system, players, and events as well as international systems, leaders and events.
6. Demonstrate an increase in interest about international developments, ability to express empathy and /or feelings of kinship about others, and degree of comfort in foreign situations.
7. Demonstrate the ability to alter one's communication and responses to reflect another's communication style and thus build relationships.

Natural Sciences Educational Objectives

1. To understand and apply method and appropriate technology to the study of the natural sciences.

2. To recognize scientific and quantitative methods and the differences between these approaches and other methods of inquiry and to communicate findings, analyses, and interpretation both orally and in writing.
3. To identify and recognize the differences among competing scientific theories.
4. To demonstrate knowledge of the major issues and problems facing modern science, including issues that touch upon ethics, values and public policies.
5. To demonstrate knowledge of the interdependence of science and technology and their influence on, and contribution to, modern culture.

Clearly, the TWU objectives in the natural sciences, particularly objectives four and five, have considerable alignment with the SENCER goals noted in previous chapters. However, it was not until the fall semester of 2007 that TWU offered a developing SENCER course.

During the summer of 2007, a team of representatives from TWU (which included the Dean of the College of Arts and Sciences, the Chairs of Biology, Mathematics and Computer Science, Chemistry and Physics; and the K-16 Education Coordinator) attended the SENCER Summer Institute 2007 (SSI 2007), held in Portland, Maine. Attendance at the summer institutes is by invitation, based on a proposal submitted by the team. In our request for an invitation to SSI 2007, we proposed developing a new, SENCER-based, multidisciplinary course titled *Our World at Risk: Global Issues in Science*. The goal of this course would be to address global issues from scientific, sociological and ethical perspectives and to demonstrate how these issues affect daily lives. Hence, this would be a course that would provide students with not only a strong scientific background but also with the foundation to think critically about global issues. With this foundation, students would be better prepared to engage in civic processes. The focus of the course would change from semester to semester with different issues highlighted. For example, issues could include the impact of climate change, the energy crisis, health and the environment, stem cell research and the human genome project. These topics are investigated from a macroscopic viewpoint (i.e., sociological and ethical) to a microscopic viewpoint (scientific). This approach encourages students to explore solutions integrating scientific and social elements. Further, we would provide students with a framework and a vocabulary to understand, evaluate and discuss science in the news. This course is ideally suited for K-12 education majors, for undergraduate non-science majors and also for undergraduate science majors.

After attending SSI 2007, the TWU team was invigorated and excited about developing the new course. However, there were questions to be addressed. What can we do to get the ball rolling? What resources do we need to develop such a course? Can we get other disciplines involved in developing SENCER courses? Since that summer, we have developed two SENCER courses and are in the process of incorporating SENCER elements into others as well. They are:

Introduction to Environmental Chemistry: Global Perspectives

During the 2006-2007 academic year (i.e., before we attended the 2007 SENCER Summer Institute) one of our faculty members developed a course titled

Introduction *to Environmental Chemistry: Global Perspectives*. It was approved by our undergraduate curriculum committee as fulfilling the requirements for both a natural science and global perspectives core course. Although not originally designed as a SENCER course, but incorporating many of those elements, it was easily modified to fulfill the SENCER objectives by including a civic engagement component. Its first offering was in the fall of 2007 and since that time, enrollment has increased from 9 students to 50 students for fall 2009. A full description of this course is described in the next chapter.

Climate Change: A Human Perspective

During the 2007-2008 academic year, a second SENCER course was developed: *Climate Change: A Human Perspective*. This course has also been approved as fulfilling the natural sciences and global perspectives core requirements and was offered for the first time in the fall semester of 2009. This course, described in the next chapter has a lecture, lab and civic engagement component as well.

In addition to these courses, other Arts and Sciences faculty have been incorporating SENCER ideals into their courses. For example:

From the Department of Biology

Environmental Biology

Students enrolled in *Environmental Biology* have a civic engagement project titled: Sustainable Solutions: Waste Reduction Education. For this project, students distribute a questionnaire to 5-7 people they know. The questions cover the following topics: 1) knowledge of environmental issues in general and of the waste problem in particular, 2) environmental worldviews and lifestyle, and 3) green activities or practical solutions to the waste problem. Data collected are evaluated for the purpose of designing and implementing educational activities by the students in the community.

Science in the Middle School and High School Classroom

This is a course for upper division pre-service science teachers. Upon completion of this course, students will be able to: plan and implement a functional science lesson, including experimentation; create and maintain a portfolio that will be a resource in their teaching field; implement science teaching techniques and strategies in the classroom to produce learning based on science inquiry; and identify appropriate methods of formative and summative assessment. This course, under development, will include a civic engagement component.

Scientific Communication

This is an upper division course targeted to for science majors. The primary goal is to improve written and verbal communication skills. Emphasis is placed on active learning techniques utilized in data collection, analysis, and communicating effectively to scientific audiences via journals and presentations. Additionally, these skills are extended by translating scientific ideas and models into a medium for the general public. Examples may include, but are not limited to, letters to the editor, presentations to a city council meeting, PTA, and civic or church groups, etc.

From the Department of Mathematics and Computer Sciences

Elementary Statistics

In the Honors section, we incorporate a community based project as a course requirement. Students are guided to pick a civic theme and to create a general research question regarding that theme. All topics are approved by the instructor. At the end of the semester the students develope a short paper about their topic. This paper is intended to help them organize their thoughts so that they can communicate this topic in an organized and meaningful way. In addition, it is required for them to find at least three journal articles or other relevant references so that they can frame their community based topic within the context of the literature. This helps make the topic more interesting - not just a bunch of number crunching - and provides perspective on the existing civic issue(s). Students will analyze data relevant to the topic; typically this is existing data from some source and many times it doesn't directly test their research question. However, they are all required to provide meaningful interpretations of the graphs and analysis they use to make their arguments. At the end of the semester, they deliver a 10-15 minute power point present of their work to the class.

Civic Engagement Faculty Learning Community

In the fall of 2008, TWU organized the Civic Engagement Faculty Learning Community. Faculty members from the Department of Biology, the Department of Chemistry and Physics, and the School of Management met on a regular basis to discuss strategieso emphasizing teaching sustainability. Articles from published journals and periodicals and books dealing with sustainability were read and discussed. Several speakers came to campus to present their efforts on sustainability as well.

SENCER Presentations

Since the incorporation of the SENCER philosophy into our academic mantra, we have endeavored to get the good word to others, not only within the SENCER community but also to the larger scientific community. Our first presentation was a poster at the SENCER Washington D.C. Symposium and Capitol Hill Poster Session. This symposium, held in the spring 2008, brought together educators from around the country to discuss SENCER programs. Demonstrating our civic engagement philosophy, we took two pre-service education majors. The highlight of the conference was meeting with our local congressman as arranged by the SENCER organizers, followed by the poster session on Capitol Hill. Our presentation focused on SENCERizing *Introduction to Environmental Chemistry*. Subsequently, we have presented posters at the 2008 and 2009 SENCER Summer Institutes as well as at the 2009 Washington meeting.

As SENCER participants and supporters, one of our goals is to introduce SENCER to educators currently not involved and to recruit them into the SENCER family. To that end, presentations about SENCER at the annual Partners in Science meeting, the Texas Association of Deans of Liberals Arts and Science meeting, and the American Chemical Society Green Chemistry and Engineering conference have been given. The Partners in Science program, initiated by the Research Corporation and now funded by the M. J. Murdoch Charitable Trust (http://www.murdock-trust.org/grants/partners-science.php), is a program which brings high school teachers into university research laboratories during the summer. The presentation to the university mentors was aimed at instilling an interest in incorporating civic engagement at the high school level through Partners in Science. The presentation to the Texas Deans was aimed at increasing awareness of SENCER to other universities and colleges in the state of Texas. Finally, the ACS green chemistry meeting, which featured sessions on education, was an excellent forum to introduce SENCER and discuss how civic engagement is related to sustainability.

Recently, symposia at the national meeting of the American Chemical Society featured science education and civic engagement. Both symposia were hosted by the Division of Chemical Education. For the 2008 fall meeting in Philadelphia, PA, Richard Sheardy organized a symposium titled "Science Education and Civic Engagement: The SENCER Approach". This symposium featured speakers who are actively involved in the project with the aim of presenting SENCER to chemical educators from theory to practice. That symposium is the foundation for this book. For the August, 2009 annual meeting in Washington, D.C., Sheardy along with Matt Fisher of St. Vincent's College and Trace Jordan of New York University organized a symposium titled "Civic Engagement and Chemistry Education" which featured speakers familiar with SENCER and also included speakers discussing science and chemistry courses and programs with service learning components. Service learning is just another way to describe civic engagement.

Future Goals

Because of the positive results and feedback we have received for our SENCER efforts, we are encouraged to keep the momentum going. With the continuing support of the College of Arts and Science and the University, we now have several initiatives to that end.

Science and Civic Engagement: A New Certificate Program

We have begun the development of a certificate program in Science and Civic Engagement. Students is this program will take up to 18 credits of science and non-science courses in a program of study aimed at linking important societal issues to science. Of the 18 credits, 9 to 12 will be in the sciences with the remaining credits coming from other disciplines such as sociology, history, or management. Furthermore, at least 6 credits must be from upper division science and non-science courses. As a capstone, students in this program will write a paper describing their experience.

Campus Surface Water Monitoring

The goal of this program is to improve the quality of water falling on university owned land and to reduce the human impact on the surrounding community. This program will be administered through our current *Introduction to Environmental Chemistry* as well as a new course (see below) dedicated to water resources in Texas. Team leaders will be trained by personnel from the River Systems Institute at Texas State University in San Marcos, TX (http://www.aquarena.txstate.edu/RSI.html). This extensive training includes techniques in the collection and analysis of water samples. These techniques and skills are then incorporated in appropriate SENCER courses. We have recently been granted a sub award from the National Center for Science and Civic Engagement to initiate this program.

New SENCER Courses

SCI 2113: Earth Science in the Context of Natural Disasters

The current volume of Hollywood disaster movies and television specials focusing on disasters past, present and fututre speaks to the public's intetrest in the forces acting on and within our planet. Earth Science (SCI 2113) is a traditional science course and usually brings a large enrollment, requiring three or four sections to be offered every semester. Registered students are typically non-science majors, most from the teacher education program. Therefore, the development of a SENCER course focusing on geologic hazards is a natural fit of an existing course with a public interest. Students discover we do not engineer our fate, but live within the constraints and by the consent of mother nature. Starting in Spring 2010 one section of SCI 2113 will be taught as *Earth Science in the Context of Natural Disasters*.

Through out the semester, students apply the scientific method to the study of natural disasters, collecting and interpreting data and communicating their findings to others. Students investigate major issues and problems likely to amplify the impact of natural hazards on society. Furthermore, they investigate the linkage between science and technology. When applied to prediction, science and technology are literally life savers.

This course not only identifies and dissects natural disasters, but it also allows students to participate in the mitigation of catastrophic events. The civic engagement element is accomplished through their participation in Disaster Training under the egis of the American Red Cross. These skills can then be communicated to family, friends, and their communities. If needed, they are trained volunteers who can positively assist the Red Cross or other emergency workers.

SCI 3545: Who Owns the Rain?

General Course Objectives: To offer an opportunity to study a critical 21st century issue from a classical liberal arts perspective by examining the science and sociology of water stress in Mexico and the American southwest.

People can live without many things and under a variety of conditions, but no one lives without water. Most water sources, both locally and globally, are shared across political boundaries. Sustainable solutions to classic upstream-downstream conflicts are a high priority for social stability. This course provides students an introduction to the science and sociological facets addressing this conflict among ten million people utilizing the Texas-Mexico Rio Grande (Rio Bravo) trans-boundary water resource.

Specific Course Learning Objectives:

1. Develop a basic understanding of water chemistry and physics.
2. Compare and contrast the evolution of transboundary water resources issues over time 1800-present.
3. Understand the value and vulnerability of science by doing science in the laboratory and in a field setting.
4. Comprehend the importance of historical conflict issues to contemporary issues and participate in these debates. Specifically, the various types of international water conventions, treaties, agreements, and how they affect water resources allocation.
5. Understand that an interdependent relationship exists between science, technology, society, and their potential impact on 21st century living.
6. Develop competencies in data collection, critical thinking, electronic database research, and presentation media. This is accomplished by critically

evaluating literature and interviewing professionals and citizens involved in international water resources planning and development.

Summary

Getting involved in SENCER is really quite easy. It does help to have a supportive administration and faculty. Attendance to a summer institute is imperative to start the project. Awards from the National Center for Science and Civic Engagement can provide funds for the development of SENCER courses. For the skeptics, a visit to the SENCER web site (www.SENCER.net) would be most informative.

Acknowledgments

We want to thank all the people at TWU for their continued support of this project and diligent work to its success: from the Department of Chemistry and Physics: Dr. Lynda Peebles, Ms. Cynthia Maguire and Ms. Jennifer da Rosa; from the Department of Biology: Dr. Sarah Macintire, Dr. Camelia Maier and Dr. Sandra Westmoreland; and from the Department of Mathematics and Computer Sciences: Dr. Don Edwards and Dr. Mark Hamner. None of this, however, would not have been possible without the insight and encouragement of the Dean of the College of Arts and Sciences, Dr. Ann Staton. Finally, we are all indebted to the National Center for Science and Civic Engagement for their financial support, through the National Science Foundation, for the development of these programs.

Chapter 4

Implementing SENCER Courses at Texas Woman's University

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We describe the development and implementation of two SENCER courses at Texas Woman's University. The first, **Introduction to Environmental Chemistry**, links important environmental issues to basic chemical principles. The second course, **Climate Change**, will demonstrate to students the complex interrelationships between climate and the human endeavor. Both courses have a civic engagement component as mandated by SENCER ideals. These course are ideally suited for non-science majors.

Introduction to Environmental Chemistry: Global Perspectives

The course was originally structured with two hours of lecture each week and a six-hour lab every other week. The lecture would build a chemical foundation for understanding environmental issues. Invited speakers would share expertise from other disciplines, such as political science, economics and communication. The lab would include field trips to environmentally relevant sites such as a water treatment plant, a "greenbelt" and a landfill. Hence, this course was an ideal starting point for the development of a rigorous SENCER course that would encompass the goals and ideals of our original proposal and incorporate a civic engagement component. Thus, with a minimal amount of time and resources available, we were able to hit the ground running and further develop this course as a SENCER course.

After attending the 2007 SENCER Summer 2007 Institute, the TWU SENCER committee encouraged "SENCERization" of SCI 2103 in Fall 2007.

This decision caused several last-minute changes. First, an environmental awareness pre-and post-survey was designed and administered. Next, guest speakers from communication, government and economics disciplines were invited to make a presentation to the class. The topic of civic engagement was actively presented, encouraged and modeled during the course. In the second semester that the course was offered, students earned 5% of the course credit by participating in civic engagement activities of their choice outside of the course. In the third semester, 10% of the course credit was earned by a combination of group projects related to sustainability issues and participation in outside civic activities related to the environment. The group projects culminated in publication of posters about various environmental sustainability concerns. Seven of the posters were included in the TWU Chancellor's Student Research and Creative Arts Symposium in April, 2009.

Introduction to Environmental Chemistry is offered with an SCI course prefix instead of a CHEM course prefix, enticing students who might otherwise choose not to take this course. That is to say, most non science majors have the perception that "science" courses are friendlier than "chemistry" courses. Thus, we seek to broaden the perspective and science literacy of future business leaders, health workers, writers, artists and (of course) teachers. Part of a liberal arts education is developing global knowledge and perspectives. This course addresses chemistry and the environment from a global perspective. One of the major objectives is to increase students' understanding of people and cultures different from their own, and to appreciate how science filters through human society over time, and is influenced by our cultures.

Catalogue Course Description

SCI 2103. Introduction to Environmental Chemistry: Global Perspectives. Chemical principles in the context of significant environmental issues. Topics include energy, biogeochemical cycles; issues such as the ozone layer, global warming and acid rain, and assessment of environmental risk. Satisfies natural science and global perspective core requirements. Two lecture and three lab hours per week. Three credit hours.

Course Format

This course has an unusual schedule. For the first two semesters it was offered, lecture met once per week for two hours. For the third term, the lecture schedule was changed to one hour twice per week. This enabled a much larger enrollment because of the way it fits our class scheduling routine. The lab is blocked for six hours every other week. Students were skeptical until they heard two magic words: FIELD TRIP! There are five or six field trips each semester and they are well worth the extra effort because of the huge amount of learning taking place on those days.

Most of the time together, whether lecture or lab, is spent using an active learning technique of one sort or another. Even lectures tend to be interactive conversations. Students frequently comment on how *fast* time flies in this class. In addition to moral support from our SENCER community, guest lecturers have visited each class to bring in a more varied perspective for the global aspects of the course. These guest experts presented information on global citizenship, how international macroeconomics affects the global environment, sustainable business practices, and how to become a participant in civic processes.

In each class, students are asked to select their preferred topics from those listed in the table of contents in the textbook. Their choices become the focal point of the course for that group of students. Some topics are preselected; students choose one or two to add to those.

Chemistry Content Covered

- behavior of atoms, ions, molecules
- properties of gases
- absorption of energy by atmospheric gases
- writing and balancing chemical equations
- stoichiometric relationships
- calculating strengths of solutions
- chemical properties of water

Textbooks

Chemistry in Context 6th ed. Lucy Pryde Eubanks, et al., © 2009 by the American Chemical Society. McGraw-Hill. ISBN 978-0-07-304876-5

Laboratory Manual to accompany Chemistry in Context 6th ed., Gail Steehler. © 2009 by the American Chemical Society. McGraw Hill. ISBN-13: 987-0-07-282836-8.

Cradle to Cradle 1st ed. McDonough and Braungart, 2002. ISBN-13: 978-0-86547-587-8. North Point Press, a division of Farrar, Strauss and Giroux; 19 Union Square West, NY 10003.

Everyone needs good tools and these books are especially well suited to our goal of learning chemistry for the purpose of applying science knowledge to environmental topics. Each chapter of Chemistry in Context is based on a major environmental issue such as, "Protecting the ozone layer," or "The water we drink." The chemical concepts are presented in context of these often complex environmental topics in much the way SENCER courses strive to connect science knowledge to complex civic issues. By engaging students in this way, this book and its accompanying lab manual are helping to develop critical thinking skills which may enable students to help resolve some of these challenges in the future.

The supplemental reading text, *Cradle to Cradle*, is used to provide an unexpected point of view so that students begin to think outside the box of their own experiences. After reading each chapter and writing a position paper responding to the ideas presented therein, students participate in a roundtable discussion of the issues. They are encouraged to express their opinions and justify them using science knowledge.

Course Outcomes

In addition to the outcomes listed above for the natural science and global perspective requirements, students should also be able to:

1 Demonstrate critical thinking skills by evaluating a variety of environmental issues, along with their risks and benefits.
2 Demonstrate an understanding of the impacts of technology on earth's material and energy resources.
3 During group discussion, make predictions about biogeochemical patterns based on knowledge of chemical principles.
4 Illustrate chemical concepts and their application to solutions via examination and explanation of case studies in an oral media presentation.
5 Demonstrate an understanding of sustainability through a writing assignment.

Performance Evaluation

Examinations

There are two (2) formal examinations, a Midterm and a Final. They are graded on the standard 100 point scale (90-100 =A, 80-89=B, etc.). These exams are geared toward measuring students' understanding of basic chemistry concepts and integration of science knowledge into the environmental issues presented. Exams are cumulative – so is life. Therefore, material covered during the first portion of the term may well reappear in context with information presented in later chapters. Both exams are open book and open note.

Labs

Experiments are designed to illustrate and demonstrate the chemistry related to environmental issues. These exercises will parallel and support lecture topics. Written reports will sometimes be required. Formal exams will include material from these exercises.

Field Trips

Field trips are a hands-on and minds-on experience for all involved. To get the maximum benefit, students are asked to prepare questions in advance, seek answers during the site visit, and share their knowledge with the class afterwards. Punctual attendance and appropriate dress are also essential.

Position Papers/Class Discussion

Each student will develop a position paper summarizing, critiquing, or reacting to discussion topics from the supplemental text, *Cradle to Cradle*, and actively participate in class discussions on each environmental issue studied during the semester.

Lectures

The lecture portion of the course is traditionally the time in which the instructor does most of the talking; however, this does not produce the optimum learning environment unless you are an aural learner, which most students aren't. The instructor's objective is to have a classroom where active learning is taking place, i.e., total "minds-on" participation. This involves instructional strategies other than passive listening and these will be used to facilitate learning. For this reason, student participation is closely related to success in this course.

Attendance – Participation

Attendance is essential as this is a very participatory class. There are many impromptu discussions and activities. Students are encouraged to participate and give their point of view or to simply ask questions.

Civic Engagement

With education comes responsibility; so it is appropriate to use our knowledge to serve the community in which we live. Therefore, a portion of the credit in this course is earned by engaging in civic activities related to the environment. This could be a group or class project to benefit the campus or local community, or individual work. These activities will require 4-6 hours of time spent outside of class and a written report about what was done, what was learned and whether it was worthwhile.

The Civic Engagement Component

Fall 2007

TWU's SENCER team has taken a leadership role by promoting a more comprehensive paper recycling program on campus. In the fall 2007 semester, the first class of nine SCI 2103 students gathered the background information necessary and wrote a comprehensive report to our campus administration encouraging them to take the next step. The background information was collected through a survey of students, faculty and staff around campus on their attitudes and practices for recycling. Based upon these surveys, the students projected Denton would save about 100 tons of waste from landfill burial each year. Further, TWU would have a larger income stream from the sale of the paper. The report played a considerable role in the expansion of the paper recycling program at TWU in the fall of 2008.

Spring 2008

Course enrollment in the second class was fourteen students. For the first time, the syllabus offered earning five percent of the course credit through participation in an outside of class civic engagement/environment-related activity. Students were allowed to choose their own preferred form of new civic engagement (not something in which they were already active), as long as it was related to benefitting the environment. A short, written report was requested describing the activity chosen and the benefits and knowledge gained by participation. In general, this was a less successful format than the group activity in the first class as described by the students themselves. Acting individually, they seemed to lose their sense of connection to the potential value of the assignment along the way.

Fall 2008

A large increase in enrollment (thirty students) created an urgent need for a more organized approach to this component of the course. Civic engagement in two outside-of-class environmental activities was required for 10 percent of the course credit, doubling the weight of this assignment. This time, the professor offered a list of approved choices as examples, along with an option to submit a request to participate in other events students might be aware of in their own communities.

In addition, the professor created an event on campus which met the assignment requirements and encouraged students in SCI 2103 to sign up. It came to be known as the Garden Workday. Twenty-three of the 30 students enrolled in the course participated along with a total of 109 students studying with four professors involved in a SENCER interest group. Collectively, all students involved donated 188 hours of labor-intensive work to improve the appearance of the TWU gardens. They cleaned and pruned existing plantings, and installed 197 new native plants that day, including 35 young trees. TWU staff provided the necessary tools. Local members of the Native Plant Society of Texas donated money and plants, and served as mentors to guide students in how to do their work. Our SENCER post-institute implementation grant was used to purchase snacks for the participants. This event served to spark a lot of interest as many of these students had never planted anything and did not know, or value, a native plant as being different than an exotic or invasive one. Several students were heard to comment that they had no idea it would be so much fun, or ask if they could come back after attending another class, even though they had already earned credit for participating.

Somehow, although it came late in the term, the Garden Workday event seemed to coalesce in the minds of students in the SENCER course in a way that caused them to value civic engagement more than they had before. Their other activities were largely individual choices among community events and virtually all wrote that they felt it extremely worthwhile, enabling them to connect science knowledge in the course with what they had done outside of class.

Spring 2009

Because the civic engagement component of the Fall 2008 class worked so well, very little change was made for the fourth class. With a total enrollment of 25 students, it was decided to plan a second Garden Workday. It was held before midterm in the semester, enabling students to make the civic connection earlier in the term. Although still in-progress, early results indicate that these students will not return to their former ignorance of the importance of such work—they now value highly the opportunity to use their science knowledge about the environment in the community.

In addition to the civic engagement component of the grade scheme in SCI 2103, other opportunities to apply science knowledge for community benefits have appeared. Two of these are worth a particular mention here because they have increased the value of science knowledge for students in our environmental chemistry course.

Members of the City of Denton watershed protection staff visited both classes in 2008-09 for two consecutive lab days. Their purpose was to train students to become certified surface water monitors in the Texas Stream Team, a citizen science program sponsored by Texas State University at San Marcos. After certification, students are encouraged to adopt a place of their choosing to test surface water quality on a monthly, ongoing basis. Several have indicated that they desire to pursue this after the course is over, a good sign that they believe it is worthwhile and important. TWU faculty have expressed an interest in becoming certified trainers in this program as well. This could be important if the city loses budgeted line items for training expenses in this program, a possibility given the difficult economic climate of our time.

Another course assignment is the sustainability group project, which is worth about 10 percent of the course credit. The first class prepared a report-of-the-whole on paper recycling as described previously. The second class did not do group projects and was less focused, possibly as a result of this omission. The third and fourth classes have been assigned into groups of three to six students and given a sustainability topic to research. Topics vary from water quality to energy alternatives to cosmetic product safety. Projects culminate in a poster presentation in class, and potentially for other audiences beyond the university. A total of ten groups have completed sustainability project posters during the 2008-09 academic year, two of which were presented by students chosen to attend the spring 2009 SENCER Washington D.C. Symposium and Capitol Hill Poster Session. While not originally conceived as a civic engagement activity, most projects lead students to the question of what to do with their new knowledge, which leads back to civic engagement: sharing science knowledge with those around us is *important*. The professor is encouraging all students to publish their posters on-campus in a student symposium and to look for opportunities to make oral presentations to campus and community organizations about the topics they studied. Over time, this will become a serious civic engagement activity resulting from SENCERization of the course.

Changing Attitudes or SCI 2103 and SALG

In a later chapter, there is an in-depth discussion of a unique assessment tool known as Student Assessment of (their own) Learning Gains, or SALG. More information about the instrument is available online at http://www.salgsite.org. It is unique in that it asks students to reflect on their own gains in knowledge and changing attitudes as a result of particular parts of a course, allowing instructors to gather learning-focused feedback from students. A basic survey form is provided for assessment at the beginning of the term, with a more detailed assessment form for the post-survey. Both are customizable for each unique situation.

The SALG survey was not used for the first year Introduction to Environmental Chemistry was offered, but was initiated with the fall 2008 term. Answers can be quite revealing, as will be shown herein. It is also possible to measure using both pre- and post-surveys, which permits faculty to understand gains in learning relative to prior knowledge of incoming students. Selected survey results are included here for the Fall 2008 class. Twenty-nine of thirty students enrolled completed the pre-survey; only 23 of the 28 students who completed the course responded to the post-survey which was administered in early January 2009.

Students reported they do understand more about the main concepts presented in this course. The respective increases in mean understanding are 1.1, 1.2, 0.7, and 1.3 (Figure 1), indicating an increase of about one level of confidence in most cases. Sustainability is taught as an overarching theme, to which other ideas are tied. It is interesting to note that the greatest increase was seen in the ability to understand the relationships between the main concepts in the course. Since interating knowledge from other venues is an often-stated course goal, this was a gratifying result of teaching this particular course.

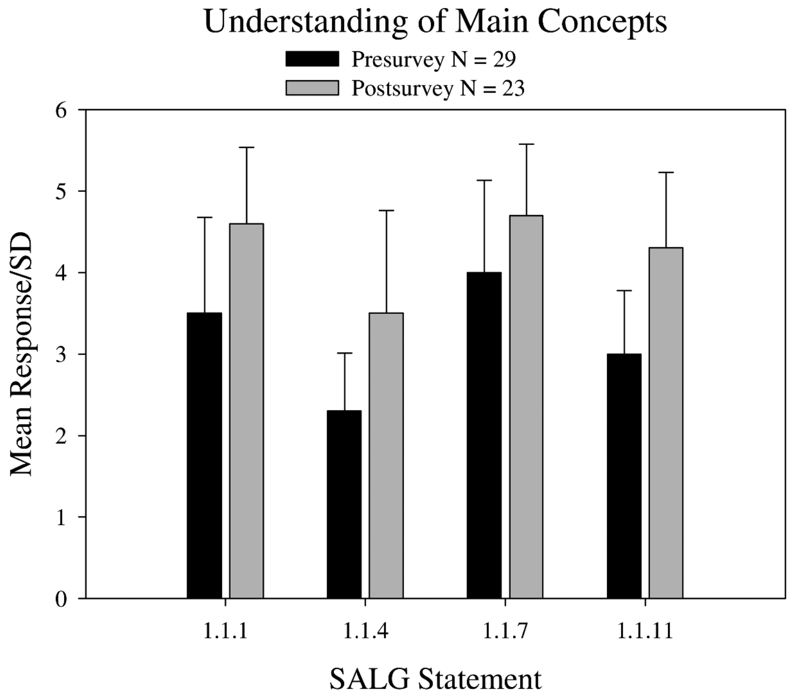

Figure 1. Understanding. Presently I understand the following main concepts that will be [or were] explored in this class: 1.1.1 Sustainabilty; 1.1.4 How to use the mole concept in chemical calculations; 1.1.7 Why there is concern about our water supply; 1.1.11 The relationships between all these main concepts. Response choices for each statement selected for inclusion were on a scale of agreement as follows: 1-not applicable, 2-not at all, 3-just a little, 4-somewhat, 5-a lot, and 6-a great deal. Data are reported as the numerical mean of all responses to each statement.

In remarks on traditional course evaluation forms, students in this course frequently write about how this experience has changed their way of looking at the environment and their place in the community. Given that information, one might expect to see a larger increase between pre- and post-survey results for statement 3.1 "Knowledgeable about important environmental issues" (Figure 2). Faculty hypothesize that students taking the SALG are more aware of their limited knowledge because of the specificity of statements on the survey, and therefore are more likely to give a candid assessment instead of a "feel-good" response. This item also had a small standard deviation (0.84 and 0.98, respectively) indicating close agreement among members of the class. The statements in Figure 3 can be divided into thinking skills (4.1-4.4) and action skills (4.10-4.15). Changes in mean response are not as consistent or dramatic in this group of statements; still, taken as a whole they describe a meaningful change in students' lives. Two statements (4.1 and 4.3) were seen to decrease slightly, possibly an indication of confusion on the part of a few students. The last four statements (4.12-4.15) deal with writing and speaking publicly on science-related issues. The mean response for each statement reflects a modest increase in behavior changes. A more noteworthy difference is in the standard deviation for these measurements, which ranges from 0.51-0.53 on the pre-survey to a three times larger value (1.46-1.59) on the post-survey. This reflects excellent agreement among students at the beginning of the course, but a wide range of responses at the end.Apparently some students are much more willing to engage in public communication about science after taking SCI 2103, while others have changed very little in this regard. On the whole, students taking this SENCERized course are better able to organize an argument, support it, and defend it to others than they were prior to enrolling, and at least a few of them are more willing to do this publicly as well.

Climate Change: A Human Perspective

The idea for **Climate Change: A Human Perspective** (SCI 2133) evolved during the 2007-2008 academic year, paralleling rejuvenated public and political interest. Global warming is a major problem facing all cultures today, yet there is much misinformation and misunderstanding circulating public forums regarding the actual science of climate change. The purpose of this new SENCER course is to clarify our state of knowledge concerning natural and man-made climate change and to examine culture's trigger and response to this change, while teaching the major tenets of earth science. Structured as two hours of lecture per week and two hours of laboratory each week, SCI 2133 is also a three credit course.

SCI 2133 premiered in Fall 2009 focusing on climate change, not only from a scientific point of view, but also from historical and sociological points of view. Several case studies used throughout the semester illuminate the role climate has played in the rise and fall of various civilizations. Past and present societies – and their unique behaviors, beliefs, attitudes, values, and ideals – are examined in the context of an ever changing climate. Changes in precipitation patterns, average annual temperatures, and vegetation distributions have influenced many cultural adaptations through the centuries. Conversely, cultural practices like land clearing, cement manufacturing, fossil fuel burning, man-made aerosol production, and large-scale agricultural and livestock activities have accelerated an already warming Earth. Moreover, additional quandaries facing society (population growth, poverty, disease, and conflict) are likely to be intensified by the effects of climate change in the future.

Climate Change: A Human Perspective satisfies both core science and global perspective requirements. Students apply the scientific method directly to investigation of climate change, and they become familiar with major scientific theories and observations like plate tectonics, radiation laws, Earth's energy balance, thermohaline circulation, atmospheric circulation, Milankovitch cycles, and the global carbon cycle. Additionally, the course focuses on major climate issues (i.e. Global Warming) facing modern science, including public policies regarding sustainable practices that may reduce anthropogenic climate forcing. Students witness the interdependence of science and technology: if it were not for

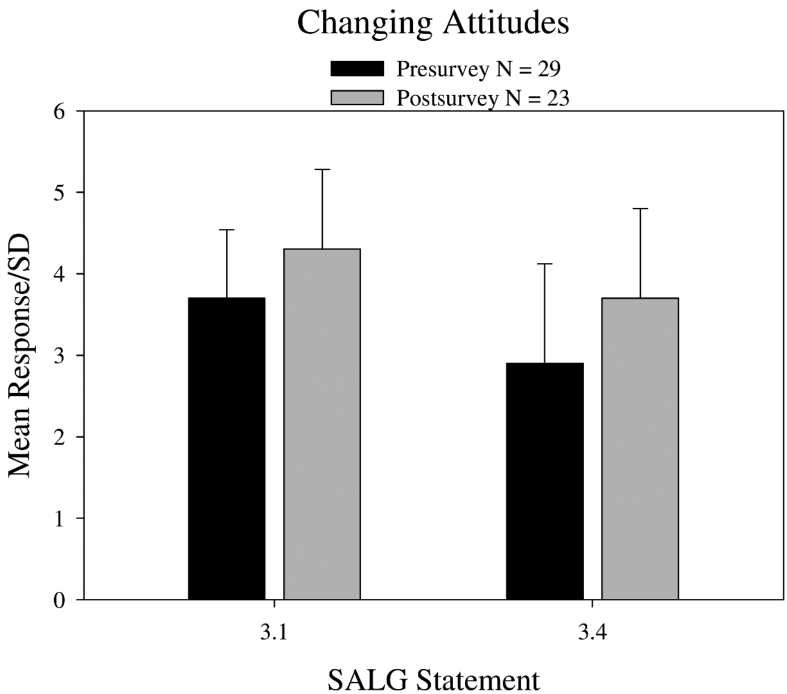

Figure 2. Attitudes. Presently I am: 3.1 Knowledgable about important environmental issues; 3.4 Interested or planning to take additional course in science. Response choices for each statement selected for inclusion were on a scale of agreement as follows: 1-not applicable, 2-not at all, 3-just a little, 4-somewhat, 5-a lot, and 6-a great deal. Data are reported as the numerical mean of all responses to each statement.

technology, we would not have the climate record that we do today. Moreover, students demonstrate the relevance of climatology and technology to modern culture when they explore the effects of future climate change on our society. With regard to global perspectives, there is a strong anthropology aspect to SCI 2133. Students shed their ethnocentric views and examine other modern cultures and past civilizations in the context of climate change.

Catalogue Course Description

SCI 2133: Climate Change: A Human Perspective. An introduction to climate change with a synthesis of major themes in meteorology, geology, oceanography, astronomy, and anthropology. Examines past, present, and future climate change in context of natural and anthropogenic forcing with special focus on man's impact on climate and climate's impact on man. Satisfies natural science and global perspectives core requirements. Two lecture and two laboratory hours a week. Credit: Three hours.

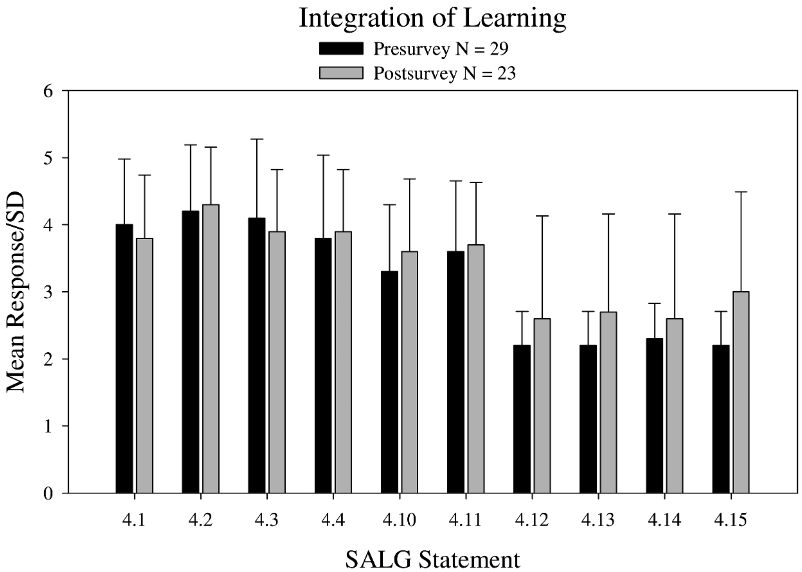

Figure 3. Integration of Learning. Presently I am in the habit of: 4.1 Connecting key ideas I learn in my classes with other knowledge; 4.2 Applying what I learn in classes to other situations; 4.3 Using systematic reasoning in my approach to problems; 4.4Using a critical approach to analyzing data and arguments in my daily life; 4.10 Discussing science-related issues informally; 4.11 Discussing civic or political issues informally; 4.12 Writing a letter to the editor about science-related civic issues; 4.13 Writing letters or emails to public officials about science-related civic issues; 4.14 Talking with public officials about science-related civic issues; 4.15 Debating or offering public comment on scientific issues. Response choices for each statement selected for inclusion were on a scale of agreement as follows: 1-not applicable, 2-not at all, 3-just a little, 4-somewhat, 5-a lot, and 6-a great deal. Data are reported as the numerical mean of all responses to each statement.

Course Format

The format for SCI 2133 is lecture and lab combined. The professor has the freedom to cover a specific topic during lecture and immediately test the concept in class, thereby facilitating comprehension. In addition, active classroom discussions are imperative to the command of such a hot topic (no pun intended!). Students debate whether or not society should attempt to reverse climate change and how we might do so. They also actively discuss climate policies currently in place, how effective they are, and whether or not they should be changed in the future. Additional reading assignments from Jared Diamond's *Collapse: How Societies Choose to Fail or Succeed* are used to enhance classroom discussions by relating climate change to the bigger picture of human history and society.

Because climate change is such an interdisciplinary topic, laboratory experimentation in this course is somewhat unconventional. The first labs focus on how climate change is measured and why it occurs. Scientists must play detective when it comes to discerning climates long past, and Earth provides many clues. One lab in particular involves a paleoclimate reconstruction. Students are given a variety of observations (ice-core data, tree-ring data, and historical records) and are asked to describe what the climate was like at a specific moment in time for a particular location. Later in the semester students examine the effects of recent climate change. They simulate the effects of climate change on different municipalities, hypothesizing as to the most vulnerable areas in terms of sea level fluctuations, drought, severe storms, and flooding. Throughout the semester labs focus on sustainable cultural practices that minimize man-made climate forcings and cultural practices that prepare us for climate change in general. In the end, students see that our best course of action when it comes to climate change is ultimately cultural adaptation.

SCI 2133 possesses a strong human component that is further emphasized with two trips. The first field trip involves a tour of the city's landfill and focuses on greenhouse gas emissions and sustainable practices. The second field trip involves a builder and architect led tour of a zero-energy house endorsed by the Department of Energy's Building America program. This experience emphasizes the importance of working with a climate (instead of against it) to to minimize the need for active space conditioning and lighting energy loads. Both field trips are united by the theme of sustainable cultural practices.

Earth Science Content Covered

- Radiation laws and solar radiation variability
- Earth's energy balance and the greenhouse effect
- Global carbon cycle
- Atmospheric structure and composition
- Atmospheric pressure, wind, and circulation
- Precipitation patterns and desertification
- Köppen climate classification and terrestrial biomes
- Climatology data collection
- Surface ocean circulation and thermohaline circulation
- Obital variations: eccentricity, obliquity, and precession
- Plate tectonic theory
- Geologic time and paleoclimatology
- Sedimentary rocks and their environments of deposition
- Glacial processes and Ice Ages
- Coastal processes and sea level change

Course Objectives

In addition to the natural sciences and global perspectives course objectives noted above, students will be able to do the following by the close of the semester:

Climate Change Objectives

- Distinguish between climate change and climate variability
- Understand the scientific method and be able to apply it to the study of climatology
- Describe positive and negative feedback mechanisms with regard to climate change and comprehend Earth as a system
- Decipher the many techniques used to measure climate change
- Appreciate the immensity of geologic time
- Comprehend natural forces that drive climate change, including, but not limited to, atmosphere – ocean interactions, fluctuations in ocean currents, volcanic eruptions, sunspots and solar activity, tidal forces, variations in Earth's orbit, plate tectonics, changes in atmospheric composition, methane hydrates in ocean sediments, and catastrophes
- Comprehend anthropogenic forces that drive recent climate change, including, but not limited to, greenhouse gas emissions, dust and aerosols, land cover and land use change, livestock and animal agriculture, and ozone depletion
- Relate various case studies of past climate change and its effect on ecosystems and civilizations
- Identify which cultural activities around the world promote anthropogenic climate change
- Identify which cultural activities around the world are successful adaptations to climate change
- Understand how global issues like population growth, poverty, disease, and conflict can be intensified by the effects of climate change
- Make predictions about future climate change and its effects on the environment, society, and biodiversity
- Explore innovative methods to cope with climate change
- Use critical thinking skills to solve problems related to climate change

SENCER (Science Education for New Civic Engagements and Responsibilities) Objectives

- Apply scientific methods and principles to address civic issues
- Identify the advantages and limitations of modern science relative to society
- Relate knowledge of climate change to current environmental/political/public issues
- Relate the principles of environmental sustainability to the study of climate change

- Demonstrate how environmental carrying capacity is strongly influenced by climate change
- Explore the effects of lowered carrying capacity on society
- Clarify how maintaining a sustainable society provides cultural adaptations in the presence of climate change
- Identify ways in which community actions can improve climate change knowledge and awareness

Textbooks

Climate Change: A Multidisciplinary Approach. 2nd Edition. Burroughs, William James. Cambridge University Press, 2007.

Collapse: How Societies Choose to Fail or Succeed. Jared Diamond. Penguin Books, 2005.

The lab manual for this course is customized through Pearson's *GEOS Custom Laboratory for the Earth Sciences* using an assortment of geology, environmental science, climatology, geography, and oceanography laboratories. Additional labs regarding paleoclimate reconstructions are prepared by the professor.

Performance Evaluation

Lectures and Reading

Lecture attendance and participation in class discussions are required for satisfactory course performance. Rather than the one-way communication of traditional lectures, the lectures of SCI 2133 require active participation and open debate regarding our society's approach and reaction to climate change. Reading homework that parallels lecture material and supplements classroom discussions is assigned periodically.

Lab Exercises

Lab exercises correspond with lecture topics and case studies and are a direct application of climatology concepts to real-world situations. Labs concentrate on four regions: 1) observing past and present climate change; 2) understanding driving forces, both natural and anthropogenic, behind climate change; 3) predicting and preparing for environmental hazards associated with recent Global Warming; and 4) implementing sustainable cultural practices to cope with climate change. The final laboratory exercise average is worth 25% of the final grade.

Exams

There are three exams given throughout the semester. Each exam is comprehensive of the new material – including lectures, labs, reading assignments, and case studies - covered up to that point. Included on the last exam is information presented during the Climate Change and Culture Project presentations. Each exam is worth 17.5% of the final grade.

Field Trip

Two mandatory field trips occur throughout the semester. Their purpose is to explore cultural practices in the context of climate change and sustainability. Students that are excused from attending one or both fields trips are expected to complete a research paper in place of each field trip. Field trip participation is worth 5% of the final grade.

Climate Change and Culture Project

The group research-and-presentation portion of this course embodies the civic engagement standards of the SENCER model. Please read below for a more detailed description of the project. The project is worth 17.5% of the final grade.

The Civic Engagement Component

The relationship between climate and humans is fascinating. Case studies given throughout the semester tell of the ongoing ballet between man and weather. Case in point: the collapse of the great Mayan civilization correlates with a devastating drought. In addition, the initial exploration of North America by Vikings was cut short by the coming of the Little Ice Age. These are among some of the cultural case studies investigated during the lecture portion of SCI 2133. Moreover, for the civic engagement aspect of this course, students complete their own cultural case study in the context of climate change.

Climate Change and Culture Project

Throughout the semester, students work on a Climate Change and Culture project, culminating with a research poster and presentation given at the end of the semester. Each student is assigned to groups of two or three or four. Groups are to research and present a cultural case study to their classmates. Groups are asked to choose a culture (can be historical or present-day) and give a general description of cultural practices (they are allowed to focus on a specific cultural practice if necessary). Projects must address the following questions:

- What cultural practices are sustainable?

- What cultural practices are synchronized with the environment to minimize the demand on resources?
- What cultural practices are likely to encourage climate change?
- What cultural practices repeal climate change?
- How is this culture prepared for climate change?
- How has this culture adapted to climate change in the past? or failed to adapt?

Evaluation of the project is based on meticulous research of topic; comprehension of material; and presentation and poster quality, creativity, and detail. Groups are required to submit several benchmark assignments throughout the semester, illustrating their project's progression. In addition, students are expected to present their research at TWU's Annual Student Creative Arts and Research Symposium.

The objective of this presentation is to increase cultural awareness. A panoramic view of cultural habits, attitudes, and actions, past and present, allows us to make better decisions regarding climate in the future. Students appreciate how a society's actions can affect the world, how a society can adapt to environmental challenges with sustainable practices, and how a global issue requires global understanding.

Summary

Since the fall of 2007, faculty in the Department of Chemistry and Physics at TWU have implemented two SENCER courses which cover important science content and have meaningful civic engagement components. Enrollment in SCI 2103 (Introduction to Environmental Chemistry) has increased from seven in the fall of 2007 to 30 in the fall of 2008. Beginning in fall 2009, two sections of 25 students each will be offered. Climate Change (SCI 2133) will be offered for the first time in the fall of 2009 and we expect significant enrollment in that course. Ultimately, the beneficiaries of these courses are the students. We are also incorporating SENCER ideals in non majors chemistry courses: CHEM 1023 (Organic and Physiological Chemistry) and CHEM 3603 (Biological Chemistry); as well as an upper division majors course: CHEM 3334 (Quantitative Analysis). In addition, faculty in the Department of Biology and the Department of Mathematics and Computer Sciences are also developing SENCER like courses.

Acknowledgments

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Chapter 5

Enhancing Chemistry Courses for Non-Majors: Implementation of Simple SENCER Teaching Strategies at the University of Dayton

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Following a frustrating experience teaching a non-majors chemistry course at the University of Dayton, I attended the 2008 SENCER (**S**cience **E**ducation for **N**ew **C**ivic **E**ngagement and **R**esponsibilities) meeting. As a result of this meeting, I implemented two important pedagogical changes in the fall of 2007. First, at the end of the lecture periods I distributed comment cards on which the students were asked to describe something in the class period which was (a) surprising, (b) interesting or useful, and (c) confusing. I used these comments as a springboard for discussion in subsequent lectures. Second, I made the learning objectives more specific and relevant to current social concerns; in short, I "SENCERized" the course. In this paper I detail the impact of these changes on student (and instructor!) attitudes and on student learning outcomes in non-majors chemistry courses, as well as the potential impact of SENCER strategies in courses for chemistry majors.

Introduction

I began my current appointment as Chair of the Department of Chemistry at the University of Dayton (UD) during the summer of 2006. As this was my first Chair position, I wanted to maximize my time commitment to Chair responsibilities. I accordingly taught our non-majors chemistry course ("Science

220"; SCI220 hereafter), which I anticipated would require little preparation, as I had taught comparable courses many times at other institutions.

My SCI220 lectures went well during the fall of 2006, during which my administrative responsibilities were reasonably light. I did not fare as well during the spring of 2007, during which my administrative responsibilities were significantly heavier, causing my lecture preparation to suffer. As a result, many of my lectures were poorly organized and presented at a level which was too advanced for the majority of the students – with predictable effects. The students were frustrated and de-motivated, and there was a palpable sense of tension in the classroom.

Because of the poor classroom dynamic, I expected to receive poor student teaching evaluations. This expectation proved prophetic: my evaluations were among the worst I have received since my first semester as a college professor (fall, 1988). Needless to say this motivated me to take corrective action. The difficulty lay in finding the time to redesign the lectures appropriately given my administrative and research responsibilities.

It was my good fortune to have a Dean who was desirous of implementing SENCER (**S**cience **E**ducation for **N**ew **C**ivic **E**ngagement and **R**esponsibilities) principles in our non-major INSS (Integrative Natural Science Sequence) courses (*1*). As a result, I was able to attend the 7th Annual SENCER Summer Institute (SSI) held at the University of Southern Maine in August of 2007. Though I benefitted from many presentations at the conference, two of the presentations impacted my teaching in immediate, positive, and practical ways.

In the first of these especially helpful sessions (*2*), Dr. Terry McGuire, Professor and Vice Chair of Genetics at Rutgers University, detailed his use of comment cards on which he asked students to describe (a) one thing mentioned in the lecture that was surprising, (b) one thing that was interesting or useful, and (c) one thing that was confusing at the end of each of his lectures. Dr. McGuire then used these comments as a springboard for discussion in the following lecture.

In the second helpful session (*3*), Dr. Barbara Tewksbury, the William R. Kenan Jr. Professor of Geosciences and Upton Chair for Public Discourse at Hamilton College, discussed course and syllabus design, with an emphasis on "SENCERization" of student learning objectives. In particular, she advocated the development of learning objectives which are (i) specific, (ii) measurable, and (iii) relevant to current social issues.

The impact of my implementation of comment cards, SENCERized learning objectives, and SENCERized essay topics in my SCI220 course during the fall of 2007, as well as their potential impact in future majors courses, were presented in preliminary form at the 236th Annual Meeting of the American Chemical Society (*4*), and are detailed below. In detailing my implementation of SENCER principles, I am as transparent as pride will allow, as the process proved to be incremental, progressive, very imperfect, and humbling. It is, in fact, ongoing. While I found the implementation of the strategies challenging, I have become a SENCER convert as a result of the positive impact the strategies have made on my own classes and teaching. The improvements have been so great, in fact, that I am now somewhat embarrassed about many of my teaching efforts prior to my attempts at SENCERization.

Figure 1 – Top

Name:______________________________ Date: ______________

1. The most *surprising* thing I heard in class today was…

2. The most *interesting/useful* thing I heard in class today was…

3. The most *confusing* thing I heard in class today was…

Figure 1. 4″ × 6″ comment cards with questions pre-printed to provide students with a clear format and to facilitate interpretation of student comments.

Implementation of SENCER Teaching Strategies in SCI220

Use of Comment Cards in Lectures

During the last five minutes of my SCI220 lectures in the fall of 2007, I distributed 4″ × 6″ comment cards with Dr. McGuire's three questions pre-printed to facilitate my interpretation of the students' comments (see Figure 1). I read the cards prior to each subsequent lecture, noting points of common surprise, interest or utility, and confusion. Summarizing the comments from ~45 comment cards in this fashion required ~20 minutes. I then used the comment summaries as a springboard for discussion during the subsequent lecture.

SENCERization of Learning Objectives

Prior to the fall of 2007, my student learning objectives in SCI220 were few (3) in number, non-specific, and only minimally quantifiable and testable, though the third of the three objectives did refer to current social issues (see Figure 2A). I accordingly began SENCERizing the learning objectives in my syllabus in accord with Dr. Tewksbury's suggestions, as illustrated in Figures 2B. The principle changes were (a) a more than threefold increase in the number of objectives (new total of 10), (b) an increased specificity of the objectives, and (c) an increase n social relevance, as each of the ten new objectives related to a current issue of personal or social concern. The objectives were developed "on the fly" and introduced gradually throughout the course of the semester.

SENCERization of Essay Topics

I provided SENCERized essay topics both prior to (Figure 3A) and during and after (Figure 3B) the fall of 2007. Though the topics used in the fall of 2006 and spring of 2007 dealt with current issues of social concern (Figure 3A), they did not have clear, detailed connections to chemistry. The revised essay topics used in the fall of 2007 and spring of 2009 (Figure 3B) were designed to address this prior deficiency by delineating clear and specific applications of chemistry to current issues of social concern.

Impact of SENCER Teaching Strategies in SCI220

Impact of Comment Cards

The utility of the comment cards became apparent within the first two weeks of my fall, 2007 class. I was immediately impressed with the obtuseness of my lectures in prior semesters, as principles which I had previously assumed were clear were in reality highly confusing to the students. The comment cards enabled me to adjust my lectures in a timely fashion, making them more relevant, understandable, and interesting. As a side benefit, offering a (very) small amount of credit for submitting comment cards appeared to increase student motivation to attend the lectures and provided me with a convenient format for keeping track of attendance. Another particularly important benefit of the comment cards is their simplicity: they can be implemented with a minimum of effort. This ease of implementation stands in distinct contrast to the SENCERization of learning objectives (see below). The comment cards may also help in the generation of learning objectives which are relevant to student interests and concerns.

The data in Table I demonstrate that SENCERization resulted in a number of significant improvements in my student evaluations for each of the five questions used by the UD Chemistry Department to evaluate faculty teaching performance. In particular, it resulted in increases of 4% (in students' self-assessment of the amount of material learned), 14% (in students' willingness to recommend SCI220 to other students), 19% (in students' willingness to recommend the instructor[!] to other students), 14% (in students' rating of the course), and 16% (in students' rating of the instructor[!]), for an overall average improvement of 13% for the five responses.

Though I have no definitive proof, I suspect that much of the improvement resulted not from changes in the content covered, or even the speed and mode of coverage, but rather from the students' perception that I was *listening to them* and was trying to cover the material *in a way designed to genuinely tie into their* *interests and benefit them*. In short, my use of the cards conveyed respect for the students and their educational and professional goals and interests. And respect begets respect: the students not only enjoyed the course more, but conveyed their enjoyment and concomitant respect back to me, which improved the social dynamic of the classroom and increased my motivation.

Impact of SENCERized Learning Objectives

In my enthusiasm for implementing learning objectives relevant to current social issues in the fall of 2007, I failed to generate learning objectives detailing more conventional – but nevertheless essential – aspects of chemistry. In fact, all of the objectives which I listed in my fall, 2007 syllabus related to current social issues (see Figure 2B). In retrospect, I regard this as a mistake, as it undersells the important role of chemical fundamentals in addressing current social issues.

The SENCERized learning objectives probably played a smaller role in the improvements in classroom dynamic, student teaching evaluations, and student learning outcomes (see below) than the comment cards – for two reasons. First, as noted above, all of the learning objectives used in the fall of 2007 related to issues of social concern, whereas a significant percentage of the exam problems did not. Second, due to time constraints, the learning objectives used in the fall of 2007 were developed and delivered *as the semester progressed*. Hence, the objectives constituted a kind of "moving target" for the students, which precluded – at least partially – their utility as learning aids. They would likely have been more useful to the students had they been delivered in their entirety at the outset of the semester. In this regard, the new and more extensive set of learning objectives which I have implemented this semester (spring, 2009; see Figure 2C) is having a large and very positive impact on classroom dynamics and student study strategies thus far this semester, as detailed in "Ongoing SENCERization of SCI220" below.

Impact of SENCERized Essay Topics

As with the learning objectives, I believe that the SENCERized essay topics played a smaller role in the improvements in classroom dynamic, student teaching evaluations, and student learning outcomes (see below) than the comment cards. I also believe, however, that the increased detail provided in the essay topics, as well as their increased emphasis on using chemistry to address topics of current social concern (Figure 3B) constitute a significant improvement over the topics used prior to the fall of 2007 (Figure 3A).

One novel approach introduced during the fall of 2007 is the use of "geographically relevant" essay topics. For example, Essay Topic #3 asks students to scientifically engage with a bill on the floor of the Ohio State House of Representatives designed to regulate the use of tanning salons by minors. In similar fashion, Essay Topic #4 asks students to weigh the economic and social benefits of coal-based technology against its social and environmental costs in light of the fact that the economies of Ohio and Kentucky are heavily invested in coal mining and coal-fired power plants.

Impact of SENCERization on Student Learning Outcomes

The final exams in SCI220 are cumulative, with some problems offered for extra credit. The averages for the final exams – normalized to account for the different amounts of extra credit offered in the different semesters – were 79.45% (fall, 2006), 72.14% (spring, 2007), and 82.24 (fall, 2007). These results suggest that student learning was enhanced as a result of SENCERization in the fall of 2007. These results are only suggestive, however, as the exams differed in length and topics covered from semester to semester. This being said, the exam averages are consistent with student evaluations, which were highest in the fall of 2007 and lowest in the spring of 2007 (see Table I).

Table I. Impact of course SENCERization on student teaching evaluations[a] in SCI220

Question	*Fall 06* [b]	*Spring 07* [c]	*Fall 07* [d]	*Fall 07 Average* / *Pre–Fall 07 Average*
Q1: Learned from Course [e]	2.4	2.0	2.3	1.04
Q2: Recommend Course [f]	1.9	1.6	2.0	1.14
Q3: Recommend Instructor [g]	2.4	1.8	2.5	1.19
Q4: Rate Course [h]	1.9	1.8	2.1	1.14
Q5: Rate Instructor [i]	2.4	2.1	2.6	1.16
Average for Q1-Q5 [j]	2.20	1.86	1.28	1.13

[a] Average scores for class based on a five-point scale in which 1 is unacceptable and 5 is outstanding. [b] Pre-SENCERization (46 students enrolled in class, 42 evaluations received). [c] Pre-SENCERization (53 students enrolled in class, 33 evaluations received). [d] Post-SENCERization (47 students enrolled in class, 37 evaluations received). [e] Students responded to the statement "I learned a great deal from this course" (Question #1). [f] Students responded to the statement "I would recommend this course to other students" (Question #2). [g] Students responded to the statement "I would recommend this instructor to other students" (Question #3). [h] Students responded to the question "Everything considered, how would you rate this course?" (Question #4). [i] Students responded to the question "Everything considered, how would you rate this instructor?" (Question #5). [j] Average score

$$\text{Q1-Q5} = \frac{\text{ScoreQ1} + \text{ScoreQ2} + \text{ScoreQ3} + \text{ScoreQ4} + \text{ScoreQ5}}{5}$$

by semester.

Ongoing SENCERization of SCI220

As is apparent from much of the discussion above, the SENCERization of my SCI220 course is very much a "work in progress", as SENCERization is an inherently incremental and progressive process. Since the fall of 2007, I have incorporated a large number of learning objectives related to conventional chemical concepts in addition to learning objectives related to current social issues. I am using this expanded set of learning objectives in my current (Spring, 2009) SCI220 course, as illustrated in Figure 2C. To date these improved learning objectives are yielding exceptionally promising results in at least three ways. First, the students in my spring, 2009 course have expressed gratitude for the highly detailed list of learning objectives. Second, and more importantly, the students are using the objectives extensively during their preparation for exams. Third, while it may go without saying, I find it easier to accomplish the new set of learning objectives because of their greater clarity and focus. For example, six of the ten SENCERized learning objectives (60% of the total) were accomplished during the fall of 2007. In contrast, more than 85% of the learning objectives have been accomplished for the material covered to date in the spring, 2009 SCI220 course.

The incremental and progressive implementation of SENCERized learning objectives highlight what I believe is one of the most important factors to be kept in mind when implementing SENCER principles into existing courses, namely that it is best to make small, workable changes rather than globally reworking a course, particularly during a first attempt at SENCERization. In fact, it is clear that while my first attempt at SENCERization (see Figure 2B) was a significant improvement over my woefully inadequate learning objectives in prior semesters (see Figure 2A), the fall, 2007 learning objectives were still poor by way of comparison with my current, expanded set of learning objectives (see Figure 2C). However, the current (Spring, 2009) set of learning objectives derives much of its quality from the earlier, less successful efforts which began with my initial attempt at SENCERization in the fall of 2007. It is noteworthy in this regard that the comment cards – which can be implemented with no prior experience and minimal time investment – can help facilitate the time-intensive task of developing good learning objectives.

I have also increased the repertoire of essay topics to include (a) the proposed but controversial connection between exposure the mercury-containing preservative present in many vaccines for childhood diseases and the subsequent development of autism and (b) the legitimacy of opinions of reputable scientists who diverge from the mainstream view that global warming is principally anthropogenic (Essay Topics #7 and #8, respectively; see Figure 3B). The addition of these two new topics illustrates the flexibility of the SENCER approach, as SENCERized learning objectives and essay topics can be added or deleted at will based upon faculty and student interest and the continually changing marketplace of social concerns.

One strategy which I have not yet attempted is use of the SENCER-SALG (**S**tudent **A**ssessment of **L**earning **G**ains) (*5*). Via pre-course and post-course tests developed by members of the SENCER community, this online tool allows students to self-assess their interest in and knowledge of science, particularly as it relates to civic engagement. I plan to use the SENCER-SALG in future iterations of SCI220, as it will help me to assess my effectiveness in motivating students to engage in science learning and civic involvement as a permanent lifestyle.

Implementation of SENCER Principles in Chemistry Majors Courses

As Dr. McGuire noted in his presentation at the 7th SSI, faculty typically do not "own" non-majors courses (*2*). I have accordingly felt free to experiment with a variety of SENCER strategies in SCI220, resulting in the positive outcomes detailed above. I have no reason to believe that the positive outcomes achieved via the use of comment cards and SENCERized learning objectives to date in SCI220 should not apply equally well to chemistry majors courses at the university level, as well as to high school and (possibly) middle school science courses. Accordingly, I plan to employ these seem strategies in my general chemistry and physical chemistry (undergraduate and graduate) courses in the future.

In contrast to non-majors courses, faculty "own" majors courses. While I have no desire to interfere with academic freedom in the teaching of these courses, I have begun to recommend the use of comment cards and SENCERized learning objectives to the chemistry faculty at UD, as well as faculty from other departments. I am obtaining significant faculty buy-in, as two members of the Chemistry faculty have begun using the comment cards, and one has begun using SENCERized learning objectives in his course syllabus – all to good effect. If the enthusiasm continues to grow, we may have the good fortune of sending a Chemistry cohort to the 2009 SSI in Chicago.

Figure 2A – Top

A. Students will apply the scientific method in chemical contexts,
B. Students will learn and utilize a number of fundamental chemical concepts as well as the basic vocabulary (nomenclature) of chemistry, and
C. Students will apply their understanding of chemistry to a number of significant issues facing contemporary society.

Figure 2A. Non-SENCERized SCI220 student learning objectives used prior to the fall of 2007.

Figure 2B - Top

A. Based on data from Garland, Garland, and Gorham,[a,b] students will develop a theory about the roles of UVA and UVB in melanoma induction (observation → hypothesis → theory).

[a]Garland, C.F., F.C. Garland, and E.D. Gorham, *Epidemiologic evidence for different roles of ultraviolet A and B radiation in melanoma mortality rates.* Ann. Epidemiol. **2003,** 13(6): pp. 395-404.

[b]Garland, C.F., F.C. Garland, and E.D. Gorham, *Rising trends in melanoma: An hypothesis concerning sunscreen effectiveness.* Ann. Epidemiol. **1993,** 3: pp. \ 103-110.

B. Students will specify the absolute and relative sizes of cells, organelles (particularly the cell nucleus), bacteria, viruses, membranes, synthetic polymers, biopolymers, molecules, atoms, the atomic nucleus, and various subatomic particles.

C. *Students will identify the ways in which chemistry addresses questions related to cosmic and biological evolution, particularly the ways nucleosynthesis ties in to the Anthropomorphic Principle and prebiotic evolution (the debunking of the Miller-Urey experiment and unanswered questions regarding the origin of life, including how evolution does not violate the Second Law of Thermodynamics).*

D. Utilizing the like-dissolves-like rule, students will explain the biological localization, half-lives and toxicological properties of fat soluble and water soluble vitamins based on the molecular structure and polarity of the compounds. Students will explain Vitamin A toxicity in light of the 1911-12 expedition of Douglas Mawson.

E. Students will specify the social and environmental assets and liabilities of various sources of energy (petroleum, coal, nuclear, wind, geothermal, and biomass) energy.

F. When presented with photos, students will be able to identify the three types of skin cancer: squamous cell, basal cell, and malignant melanoma. Students will understand the risk factors associated with each type.

G. Using articles by Garland, Garland, and Gorham[a,b] Giovannucci,[c-e], Koh, Kligler, and Lew,[f] and Tavera-Mendoza,[g] students will (1) assess their relative risks of melanoma, (2) perform a risk/benefit analysis regarding exposure to 3 wavelengths of light in the UVA/UVB range, factoring in UVA/UVB ratios and Vitamin D photosynthesis, (3) specify whether ozone depletion should increase or decrease risk of melanoma, (4) decide between various commercial sunscreens as to which would provide the best protection, and (5) arrive at a personal sun exposure plan

[c] Giovannucci, E., *The epidemiology of vitamin D and cancer incidence and mortality: A review (United States).* Cancer Causes Control **2005,** 16(2): pp. 83-95.

[d] Giovannucci, E., *Commentary: Vitamin D and colorectal cancer - twenty-five years later.* Intl. J. Epidemiol. **2005,** 35: pp. 222-224.

[e] Giovannucci, E., et al., *Prospective study of predictors of vitamin D status and cancer incidence and mortality in men.* J. Nat'l. Canc. Inst. **2006,** 98(7): pp. 451-459.

[f] Koh, H.K., B.E. Kligler, and R.A. Lew, *Sunlight and cutaneous malignant melanoma: Evidence for and against causation.* Photochem. Photobiol. **1990,** 51: pp. 765-779.

[g] Tavera-Mendoza, L.E. and J.H. White, *Cell defenses and the sunshine vitamin.* Scientific American **2007,** 297(5): pp. 62-72.

H. *In light of skin photochemistry, students will explain how skin color fits or does not fit an evolutionary model and an intelligent design model of human origins.*

I. *Students will estimate the average amount of normal and trans fat they eat per day. They will be able to specify the chemical differences between trans fat and normal fats (saturated and unsaturated, cis and trans, as well as the chemical origins of the differences in physical properties of cis and trans fats).*

J. *Using the carbon-to-oxygen ratio, students will approximate the caloric values of various foods based on molecular structure (particularly fats, carbohydrates, proteins, and ethanol).*

Figure 2B. SENCERized SCI220 student learning objectives used during the fall of 2007. Italicized objectives were not accomplished during the fall of 2007.

Figure 2C - Top

Chapter 1: The Air We Breathe

1-A Students will specify the difference between mixtures, pure substances, compounds, and elements, and describe two techniques by which mixtures can be separated into pure substances.

1-B Students will describe the three states of matter (solid, liquid, and gas) at both the atomic and macroscopic scales.

1-C Students will specify the relative percentages of oxygen, nitrogen, and carbon dioxide in the atmosphere
and state at least one practical consequence of these percentages.

1-D Students will describe the differences between atoms and molecules and specify their relationships to elements and compounds.

1-E Students will name binary compounds and simple hydrocarbons using standard chemical prefixes (see p. 28 of text)

1-F Students will balance simple chemical equations – particularly equations related to combustion.

1-G Students will name at least three primary air pollutants, one secondary air pollutant, their means of generation, and their impact on human health.

Chapter 2: Protecting the Ozone Layer

2-A Students will draw a schematic diagram of an atom, specifying the location of protons, neutrons, and electrons, the relative size of the atomic nucleus and the atom as a whole, and the relative charges and masses of protons, neutrons and electrons.

2-B Students will specify the sizes of cells, cell nuclei, bacteria, viruses, molecules, atoms, atomic nuclei, protons, neutrons, and electrons (see Figure 2-6, p. 70 of textbook).

2-C Students will specify the element, the isotope number, and the electrical charge of an atom based on the numbers of protons, neutrons, and electrons it contains.

2-D Students will predict the formula of any compound formed between any two representative elements (*i.e.*, elements belonging to Groups 1A-8A in the Periodic Table).

2-E Students will detail the relationship of electricity to chemical bonds, and will explain the difference between covalent and ionic bonds.

2-F Students will draw Lewis structures for simple covalent compounds, showing how electrons are distributed in bonding pairs and lone pairs.

2-G Students will specify the relationship between wavelength λ, frequency ν, and speed c for a light wave.

2-H Students will calculate the energy E_λ of a light wave in Joules (J) given its wavelength λ? in nanometers (nm). Students will specify the relative energies of representative, ultraviolet (λ = 250 nm), visible (green; λ = 500 nm), and near infrared (λ = 750 nm) light waves.

2-I Students will identify the major regions of the electromagnetic spectrum in terms of energy E_λ, frequency ν, and wavelength λ. Students will specify the wavelength ranges of visible and ultraviolet (UVA, UVB, and UVC) light waves.

2-J Students will explain how light absorption and light scattering impart color to blue, green, red, white, and black liquids.

2-K Students will explain why it is desirable (undesirable) from a chemical standpoint for ozone to be present in the upper (lower) atmosphere.

2-L Students will explain the chemical origins, geographic extent, and health implications of the ozone hole. Students will specify two current strategies for eliminating the ozone hole, and explain the chemical reasoning on which these strategies are based.

2-M Students will develop a theory about the roles of UVA and UVB in melanoma induction (observation → hypothesis → theory) based on recent scientific literature.[a,b]

[a]Garland, C.F., F.C. Garland, and E.D. Gorham, *Epidemiologic evidence for different roles of ultraviolet A and B radiation in melanoma mortality rates.* Ann. Epidemiol. **2003**, 13(6): pp. 395-404.

[b]Garland, C.F., F.C. Garland, and E.D. Gorham, *Rising trends in melanoma: An hypothesis concerning sunscreen effectiveness.* Ann. Epidemiol. **1993**, 3: pp. 103-110.

2-N Students will identify the three types of skin cancer – squamous cell carcinoma, basal cell carcinoma, and malignant melanoma – when presented with photos. Students will detail the risk factors associated with each type.

2-O Students will (1) calculate the UVA/UVB ratios for three sets of light irradiation conditions (300 nm only, 50% each of 300 nm and 360 nm, and 360 nm only), (2) specify which of the irradiation will most effectively induce vitamin D photosynthesis, and (3) perform a risk/benefit analysis for the induction of melanoma in individuals exposed to these three sets of irradiation conditions based on the UVA/UVB ratios and the roles of UVA and UVB in vitamin D photosynthesis.

2-P Students will (1) specify whether the ozone hole is predicted to increase or decrease the incidence of melanoma, (2) decide which among a list of commercial sunscreens most effectively minimizes melanoma risk, (3) assess their personal risk for melanoma based on their skin type and history of sun exposure, and (4) develop a personalized sun exposure plan based on recent articles in the scientific literature1-7 (see list of references at end of syllabus).

Chapter 3: The Chemistry of Global Warming

3-A Students will specify the shapes of molecules based on their Lewis structures.

3-B Students will define the greenhouse effect and specify at least three greenhouse gases.

3-C Students will explain the relationship of molecular vibrations to the greenhouse effect.

3-D Students will specify three reasons why many scientists generally believe that anthropogenic carbon dioxide and other greenhouse gases are causing the earth's temperature to rise. Students will specify two reasons some scientists question this conclusion. (See Essay Question #7: "Divergent Voices on Global Warming").

3-E Students will detail three current strategies specified in the Kyoto Protocol for preventing anthropogenic global warming, and detail their relative costs and practicability.

3-F Students will describe at least two ways in which global warming may contribute to future international conflicts.

Chapter 4: Energy, Chemistry, and Society

4-A Students will define the following concepts: the mole, Avogadro's Number N_A, molar mass m for elements and compounds, mass ratios, mass percentage, potential and kinetic energy, work, heat, temperature, Joule, calorie, the First Law of Thermodynamics, heat of combustion, bond energy, exothermic, endothermic, entropy, and the Second Law of Thermodynamics.

4-B Students will calculate the molar mass of a compound given its molecular formula and the molar masses of its constituent elements.

4-C Students will calculate the mass ratio and mass percent for each constituent element in a compound given its molecular formula.

4-D Students will use the carbon-to-oxygen ratio (C/O ratio) to predict the energy content of various fuels based on their molecular structure.

4-E Students will balance combustion reactions for various fuels and calculate their heats of combustion in kilojoules per mole (kJ $mole^{-1}$) and kilojoules per gram (kJ g^{-1}). Students will calculate the number of grams of CO_2 generated per gram of fuel (g CO_2/g fuel) and per kilojoule of heat released (g CO_2 kJ^{-1}) to determine the environmental CO_2 burden associated with the various fuels.

4-F Students will specify the four "strokes" involved in the operation of an internal combustion (automobile) engine.

4-G Students will define the following: octane number, straight run gasoline, catalytic cracking, straight chain and branched chain hydrocarbons, and isomers.

4-H Students will explain the chemical rationale for increasing octane number by increasing the extent of branching, the use of oxygenated fuels, and the use of tetraethyl lead.

4-F Students will specify the financial, social and environmental assets and liabilities of various non-renewable (petroleum, coal, and nuclear) and renewable (hydroelectric, wind, geothermal, and biomass) sources of energy.

Chapter 5: The Water We Drink

5-A Students will specify the various natural sources of fresh water, as well as the relative purities of bottled, tap, and filtered water.

5-B Students will rationalize the solvent properties of water in terms of its polarity and hydrogen bonding properties.

5-C Students will describe at the molecular level what happens when ionic compounds dissolve in water, and will predict the relative solubility of covalent compounds based on their molecular structure.

5-D Students will describe the chemical factors which make water essential for most living systems.

Chapter 6: Neutralizing the Threat of Acid Rain

6-A Students will define the following concepts: acid, base, alkali, hydronium ion, hydroxide ion, neutralization, and pH.

6-B Students will determine whether a given acid or base is strong or weak by memorizing the small number of strong acids and strong bases.

6-C Students will calculate the pH of a variety of acidic and basic solutions given the concentration of hydronium or hydroxide ions present.

6-D Students will explain the industrial origin, geographic extent, and environmental impact of acid rain, the chemical reactions which lead to its formation, and various strategies which have been proposed to remediate this environmental problem.

Chapter 7: The Fires of Nuclear Fission

7-A Students will detail and contrast the design of nuclear reactors and coal-burning power plants.

7-B Students will define the following: nuclear fission, nuclear fusion, radioactive (α, β, and γ) emission, and radioactive half-live, and rationalize why these processes release tremendous amounts of energy ($E = mc^2$).

7-C Students will rationalize the levels of danger posed by α, β, and γ radiation, as well as their medical uses.

7-D Students will detail the risks and benefits of fission-based nuclear power, with an emphasis on nuclear waste storage. Students will contrast the relative utility of nuclear fission and fusion for generating electricity.

7-E Students will detail the principal events and personalities of the Manhattan Project. Students will develop a personal philosophy regarding the ethics of nuclear warfare in light of America's use of atomic weapons in Japan, the nuclear stalemate between the United States and the Soviet Union during the Cold War, and contemporary threats posed by terrorists.

Chapter 10: Manipulating Molecules and Designing Drugs

10-A Students will detail the major categories of drugs: analgesics, anesthetics, antibiotics, antivirals, antiallergenics, steroids, and psychotherapeutics.

10-B Students will detail the relative merits of prescription, generic, over-the-counter (OTC), and herbal medications.

10-C Students will detail the chemistry of aspirin and the beneficial medical effects it provides.

10-D Students will detail modern strategies for drug design, testing, approval, and marketing.

10-E Students will define the following terms: LD_{50} and half-life.

10-F Students will assess the benefits and risks of a prescription drug based on its product literature, and will devise personal strategies for deciding when to use prescription, generic, over-the-counter, and herbal medicines.

10-G Students will detail the major categories of psychoactive compounds: stimulants, sedatives and depressants, anti-anxiety agents, anti-depressants, anti-psychotics, and hallucinogens.

10-H Students will detail the chemistry underlying addiction.

Chapter 11: Nutrition – Food for Thought

11-A Students will detail the chemical properties, biological function, and dietary sources of the macronutrients (fats, carbohydrates and proteins) and micronutrients (vitamins and minerals).

11-B Students will quantify the caloric values of fats, carbohydrates, proteins, and ethanol based on their molecular structures and carbon-to-oxygen ratios.

11-C Students will explain the cellular localization, half-lives and toxicity of fat-soluble and water-soluble vitamins using the like-dissolves-like rule, and will explain Vitamin A toxicity in light of the 1911-12 expedition of Douglas Mawson.

Figure 2C. SENCERized SCI220 student learning objectives used during the spring of 2009. Italicized objectives were not accomplished in during the fall of 2007.

Figure 3A – Top

Essay #1: In his article entitled "The Doors of Perception: Why Americans Will Believe Almost Anything" Dr. Tim O'Shea outlines his belief that Americans don't think for themselves. Is this true? If so, how can we protect ourselves from being duped by misinformation?
http://www.mercola.com/2001/aug/15/perception.htm

Essay #2: Many of us would not want to take a medication or give one to our child or a loved one if we believed it had not been tested. Should researchers be allowed to test drugs on convicts or animals? If not, then who should test these compounds for safety, and how?
http://www.dooyoo.co.uk/speakers_corner/discussion/vivisection/_review/152047/
Also:
http://www.wealth4freedom.com/truth/SECRET2.htm

Essay #3: It is currently fashionable to consider genetically altering many things, including food crops. Given the potential health and ecological risks involved, should we genetically alter foods to increase disease resistance of crops and to improve food production to feed the hungry?
http://www.mercola.com/2001/jul/14/gm_foods.htm

Essay #4: Should all drugs, vitamins, over the counter aspirin, *etc.* be regulated by the government? Should any medications be restricted for purchase or regulated by the Drug Enforcement Agency? Should it be legal to import drugs from other countries for personal use?
http://www.thenewamerican.com/tna/1993/vo09no22/vo09no22_vitamins.htm

Essay #5: Given the potential health risks involved, should vaccinations be a legal requirement for children attending public schools? Is a vaccination requirement an infringement on parental rights?
http://www.mercola.com/forms/vaccine_teleconference.htm

Essay #6: In light of surveillance issues related to the Patriot Act, should manufacturers be allowed to place tracking or recording devices (*i.e.*, black boxes) in cars and other modes of transportation without notifying the purchaser that the device is present? Does the presence of such devices violate the consumer's right to privacy?
http://www.foxnews.com/story/0,2933,132056,00.html
http://www.drivers.com/article/248/
http://www.seniormag.com/headlines/blackboxcars.htm

Figure 3A. SCI220 essay topics used during the fall of 2006 and spring of 2007. These topics relate to current issues of social concern, but do not all have a clear tie-in to chemistry.

Figure 3B – Top

Essay Topic #1: Currently, energy derived from nuclear fission is widely utilized throughout the world, including the US. Yet, nuclear fission carries with it inherent risks which make it undesirable in some ways. Nuclear fusion appears to few if any of the of the risks of nuclear fission, making the development of nuclear fusion reactors highly desirable. Nevertheless, there are no functional nuclear fusion reactors operating in the world today. Specify the advantages of fusion energy over fission energy and conventional petroleum and coal-based energy sources. Then specify how the development of nuclear fusion reactors could lead to a reduced environmental carbon footprint for the US, particularly in light of the fact that fusion engines cannot be placed on cars, which are one of the leading sources of CO_2 in the US. In light of your findings, should the US make major investments in fusion energy?
http://www.npr.org/templates/story/story.php?storyId=13746131
Deutch, J.M. and E.J. Moniz. The nuclear option. *Scientific American* **2006**, 295(3), 76-83 and references cited therein.

Essay Topic #2: It has long been known that exposure to ultraviolet light from the sun contributes strongly to the development of skin cancer.[a-d] It is somewhat surprising, then, that some recent findings indicate that the use of some sunscreens has led to *increased* rates of malignant melanoma, the most deadly form of skin cancer.[b] Furthermore, ultraviolet light from the sun contributes to the generation of Vitamin D, which is now believed to play a significant role in the prevention of many types of cancer.[e-g] Hence, sun exposure has both procarcinogenic and anticarcinogenic (cancer-inducing and cancer-preventing) effects. Describe how individuals can maximize the benefits of sun exposure while at the same time minimizing the risk of sun exposure and sunscreen usage? In light of your findings, describe your personal plans for exposure to the sun.
http://www.npr.org/blogs/news/2007/08/fda_its_time_to_tell_the_truth_1.html
http://www.npr.org/templates/story/story.php?storyId=13906486

[a]Garland, C.F., F.C. Garland, and E.D. Gorham. Epidemiologic evidence for different roles of ultraviolet A and B radiation in melanoma mortality rates. *Ann. Epidemiol.* **2003**, 13(6), 395-404.
[b]Garland, C.F., F.C. Garland, and E.D. Gorham. Rising trends in melanoma: An hypothesis concerning sunscreen effectiveness. *Ann. Epidemiol.* **1993**, 3, 103-110.
[c]Koh, H.K., B.E. Kligler, and R.A. Lew. Sunlight and cutaneous malignant melanoma: Evidence for and against causation. *Photochem. Photobiol.* **1990**, 51, 765-779.
[d]Tavera-Mendoza, L.E. and J.H. White. Cell defenses and the sunshine vitamin. *Scientific American* **2007**, 297(5), 62-72.

[e]Giovannucci, E. The epidemiology of vitamin D and cancer incidence and mortality: A review (United States). *Cancer Causes Control* **2005**, 16(2), 83-95.
[f]Giovannucci, E. Commentary: Vitamin D and colorectal cancer - twenty-five years later. *Intl. J. Epidemiol.* **2005**, 35, 222-224.
[g]Giovannucci, E., *et al.* Prospective study of predictors of vitamin D status and cancer incidence and mortality in men. *J. Nat'l. Canc. Inst.* **2006**, 98(7), 451-459.

Essay #3: Ohio House Bill 230 (H.B. 230) submitted to the floor of the Ohio State House of Representatives in Columbus on May 22, 2007 mandates a change in the law for patronage of tanning salons by minors. The current law states that those under the age of 18 are not allowed to utilize tanning salons without parental consent unless they need it for medical purposes. H.B. 230 will forbid all non-medically mandated patronage of tanning salons by minors. Hence, unless required for medical purposes, minors will not be allowed to use the services of tanning salons – even if their parents do not object. Explain why ultraviolet light such as that present in generated in tanning beds is harmful to the skin in ways that visible light is not. Then discuss the economic implications for H.B. 230 for tanning salons such as *Tanning on the Dark Side* near campus? Do you agree with H.B. 230? Why or why not?
http://www.legislature.state.oh.us/analysis.cfm?ID=127_HB_230&ACT=As%20Introduced&hf=analyses127/h0230-i-127.htm
http://www.legislature.state.oh.us/bills.cfm?ID=127_HB_230
Tavera-Mendoza, L.E. and J.H. White. Cell defenses and the sunshine vitamin. *Scientific American* **2007**, 297(5), 62-72.

Essay #4: Coal mining is important to the economies of Kentucky and Ohio. Yet, coal is very "dirty" from an environmental standpoint. Specify at least three reasons why coal is considered environmentally dirty. Hence, the economic and environmental impact of coal usage conflict with each other. In light of this economic/environmental conflict, should Kentucky and Ohio continue to invest in coal mining and coal-based energy development? Why or why not?
http://www.npr.org/templates/story/story.php?storyId=6921983
Hawkins, D.G., D.A. Lashof, and R.H. Williams. What to do about coal. *Scientific American* **2007**, 295(3), 68-75 and references cited therein.
Collins, W., *et. al.* The physical science behind climate change: Why are climatologists so highly confident that human activities are dangerously warming the earth? *Scientific American* **2007**, 297(2), 64-71 and references cited therein.

Essay #5: The use of the synthetic insecticide DDT came under attack in the 1960s, in part as a result of Rachel Carson's environmental treatise *Silent Spring*. DDT use is associated with the decline of various endangered species of birds because it hinders the proper formation of eggshells. Yet, the incidence and mortality of human malaria in Africa and Asia rises when DDT use is prohibited because DDT is the most effective means available for killing *Anopheles* mosquitos, which transmit the malaria parasite to humans. Specify the chemical formula of DDT and explain in simple terms the chemical mechanisms by which it kills mosquitos and interferes with eggshell formation. Then argue for or against its use based on the implications for its use on bird and human populations.
http://www.npr.org/search.php?text=ddt+and+malaria&sort=DREDATE%3Anumberdecreasing&aggId=0&prgId=0&topicId=0&how_long_ago=0
Jeffrey Sachs, *The End of Poverty: Economic Possibilities for Our Time*, Penguin Group (USA), **2005**.
Rachel Carson, *Silent Spring, 40th Anniversary Edition*, Houghton-Mifflin, **2002**.

Essay Topic #6: Should all drugs, vitamins, over the counter aspirin, *etc*. be regulated by the government? Should any medications be restricted for purchase or regulated by the Drug Enforcement Agency? Should it be legal to import drugs from other countries for personal use?
http://www.thenewamerican.com/tna/1993/vo09no22/vo09no22_vitamins.htm

Essay Topic #7: Although the majority of the scientific community believes that global warming is an anthropogenic phenomenon, there are a number of reputable voices in the scientific community who disagree with this majority viewpoint. Some of these individuals have made very strong statements attempting to debunk the anthropogenic component to global warming. For example, Ivar Giaever, a 1973 Nobel laureate in physics, has called global warming a "new religion", and Kiminori Ito, an environmental physical chemist living in Japan has called global warming "the worst scientific scandal in history" (see *Cincinnati Enquirer* reference below). Weigh the evidence presented in two or more of the articles presented below against that favoring the anthropogenic global warming hypothesis presented in your textbook. State which you believe has the stronger case. Justify and document your conclusions.
International Climate Science Coalition.
http://www.climatescienceinternational.org/index.php?option=com_content&task=view&id=66

Forget global warming – the real problem is cooling. Walter Williams, Cincinnati Inquirer, Editorial Section, Dec. 28, **2008**.
Climate Confusion: How Global Warming Hysteria Leads to Bad Science, Pandering Politicians and Misguided Policies that Hurt the Poor, Roy Spencer, PhD, Encounter Books, New York, **2008**; ISBN-13: 978-1-59403-210-3.
An Appeal to Reason: A Cool Look at Global Warming, Nigel Lawson, Duckworth Publishers UK, **2008**; ISBN: 9780715637869.
*The Deniers: The World Renowned Scientists Who Stood Up Against Global Warming Hysteria, Political Persecution, and Fraud**and Those Who Are Too Fearful to Do So*, Lawrence Solomon, Vigilante Books, USA, **2008**; ISBN: 9780980076318.
Shattered Consensus: The True State of Global Warming, Patrick J. Michaels, PhD., Rowman & Littlefield Publishers, **2006**; ISBN-13: 978-0-7425492-3-4

Essay Topic #8: Mercury is a heavy metal which acts as a neurotoxin and is present thimerosol, which is used in small quantities as a preservative in childhood vaccines. As the first symptoms of autism – a sometimes extreme neurological disorder which leads to severe social impairment in children – frequently become manifest around the age at which children receive vaccinations, there has been significant debate as to whether the mercury present in thimerosol actually *causes* autism and whether or not parents should be required by law to have their children vaccinated. The first two websites below present evidence which argues against a causal connection between thimerosol and autism, whereas the last reference presents evidence which supports a causal connection. Compare the evidence presented at these websites and state which you believe has the strongest case and why. Then answer the question "Should parents be required by law to have their children vaccinated against potentially devastating childhood diseases?" Answer this latter question in light of the fact many childhood diseases were epidemic prior to the development of the vaccines.
http://www.sciencedaily.com/releases/2008/04/080424120953.htm. Be sure to check a number of the "Related Stories" listed at this website.
http://www.quackwatch.org/03HealthPromotion/immu/autism.html
http://www.thinktwice.com/autism.htm

Figure 3B. SENCERized SCI220 essay topics #1-#6 were used during the fall of 2007. Topics #7 and #8 were added in the spring of 2009.

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References

1. The Integrative Natural Science Sequence (INSS) is an 11-credit hour course sequence which is required for all students in the College of Arts and Sciences at the University of Dayton not majoring in mathematics, the natural sciences, or pre-medicine. The INSS is centered on common themes of energy, evolution, and the environment, and is comprised of 3 credit hour lecture courses in physics, chemistry, geology, and biology, plus accompanying 1-hour laboratory courses. All students are required to take physics and biology; students must choose to take either chemistry or geology, for a total of 9 lecture credit hours. The balance of the additional two hours is comprised of any two of the four 1-hour laboratories.
2. McGuire, T. SENCER and the Education of Science Majors. http://www.sencer.net/Institutes/pdfs/SSI_2007/Presentations/CS2_Science_Majors.pdf (accessed February 25, 2009).
3. Tewksbury, B. Designing a SENCER Course: Don't Just Beat It to Fit and Paint It to Match. http://www.sencer.net/Institutes/pdfs/SSI_2005/DesigningaSENCERCourse.pdf (accessed February 25, 2009).
4. Masthay, M. B. Enhancing Chemistry Courses for Non-Majors: Implementation of Two Simple SENCER Teaching Strategies, 236th Annual Meeting of the American Chemical Society, August 17−21, 2008, Philadelphia, PA. http://oasys2.confex.com/acs/236nm/techprogram/P1206776.HTM (accessed February 25, 2009).
5. SENCER Home Page. http://www.sencer.net/Assessment/assessmenttools.cfm (accessed February 25, 2009).

Chapter 6

Implementing Civic Engagement Ideals in Analytical Chemistry

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This paper describes implementation and evaluation of a majors level Quantitative Analysis cours taught for five years in a civic engagement format at Roosevelt University. Assessment of the civic engagement approach was made through standardized exams, grade distributions, retention data, and student surveys. Standardized exam scores indicate satisfactory understanding of core majors chemistry content relative to national norms. On a five unit scale, SALG results indicate gains of at least one unit in self-reported learning on lecture objectives (1.0 ± 0.8), laboratory objectives (1.1± 0.7), and integration of knowledge (1.4 ± 0.5). Smaller gains were observed on general science objectives (0.5 ± 0.5), civic engagement (0.6± 0.3), and interest in science (0.3 ± 0.6). Due to lack of control sections, it is not possible to say whether the civic engagement format is more effective than a traditional course format.

Science Education for New Civic Engagement and Responsibility, or SENCER, is a national science education initiative funded by the National Science Foundation's Division of Undergraduate Education. The goal of the SENCER initiative is to improve undergraduate teaching in Science, Technology, Engineering and Mathematics (STEM) disciplines through encouraging the use of civic engagement in teaching. Testable hypotheses of the SEN/CER approach are that civic engagement courses will increase students' interest in STEM disciplines, encourage students to connect their STEM learning to their other studies, strengthen students' understanding of science content and of the scientific method, and increase students' capacity for responsible work and citizenship. The SENCER initiative supports a wide range of activities, include STEM faculty development through national, regional and local workshops; small course development grants; assessment strategies and tools including the Student Assessment of Learning Gains (SALG); and the dissemination of SENCER model courses, which are field-tested, peer-reviewed courses contributed by faculty at institutions throughout the nation. Model courses, which are downloadable from the SENCER web site (*1*), include course descriptions, detailed syllabi & reading assignments, handouts, descriptions of student projects and assignments, discussion of the role of the course in the host institution's curriculum, and course evaluation data. These model courses illustrate how to implement civic engagement ideals in general education and majors level courses in a wide variety of STEM disciplines.

Characteristics of Civic Engagement Courses

As described by SENCER (*1*) and summarized by Middlecamp et. al. (*2*), civic engagement courses aspire to a series of ideals, including to robustly connect science and civic engagement by teaching through complex public issues to basic science; to invite students to put scientific knowledge and the scientific method to immediate use on matters of immediate interest; to treat the intellectual project as practical and engaged from the start; to extract from immediate issues of societal concern the larger, common lessons about scientific processes and methods, and to locate the responsibility of discovery as the work of the student.

I would like to suggest that from these ideals, three principles can be identified which are central to the SENCER model courses and which lie at the core of any civic engagement course. The first hallmark of a civic engagement course is use of active learning pedagogy. The second characteristic of a civic engagement course is an exceptionally close integration of science content and a central societal issue. In this respect, the civic engagement approach builds upon and extends successful science and society approaches exemplified by courses such as Chemistry in Context (*3*). The difference is largely one of degree and focus. Civic engagement courses tend to more tightly integrate the science with a single unifying theme, as opposed to more loosely linking the scientific content with a series of compelling but unrelated social, political, economic and ethical issues. Many civic engagement model courses treat the societal issue as the core of the course, and teach through the issue to the underlying science (*2*, *4*). The third hallmark of a civic engagement course is to engage the student in immediate application of knowledge to issues of relevance to the student, community or society. To do this, civic engagement courses often incorporate strategies such as service learning and project-based learning (*5–7*), where the project is thematically linked to the focal theme of the course.

As shown in Table I, civic engagement model courses have been adopted for disciplines including biology, chemistry, geology, environmental science, and mathematics, as well as wide variety of interdisciplinary topics. The civic engagement model grew out of the need for quality, engaging general education in the sciences. Of the 37 SENCER model courses disseminated between 2001-2008, 22 of them, or 59% of the model courses to date, have been offered by their host institutions for non-majors, in fulfillment of general education science requirements. An additional 22% are learning community courses which satisfy multiple general education requirements. Civic engagement courses have proven successful at increasing interest, enrollment and student completion rates in general education science courses for non-majors (*2*, *4*, *7*).

Civic Engagement Courses for Majors

There is growing interest in the science education community in extending the civic engagement model to the majors, and in determining whether it will yield gains in science interest, content knowledge, higher order learning skills, civic engagement, or student retention in STEM majors. However, there are significant barriers to implementation of civic engagement ideals in majors course, particularly concern about content, since courses for majors often have very clearly-defined expectations for the body of knowledge that students must master. As shown in Table I, several of the SENCER model courses are majors-level classes which are required for or satisfy major electives in specific STEM majors at the host institution. These model courses represent several disciplines, including biology, mathematics, geology, computer science and chemistry. Even among these courses, however, there is little published quantitative data to permit evaluation of whether the civic engagement model in successful in the primary goals of conveying content knowledge, developing higher order skills, improving student attitudes towards science, and increasing students' sense of civic engagement.

Within the chemistry education literature, there are also many examples of majors-level courses which exhibit one or more hallmarks of a civic engagement course, such as service learning projects (*8–10*), applied laboratory modules with societal relevance (*11–13*), or thematic links between lecture content and societal issues (*14*). Several of these courses or modules report improved student learning, retention of students in the course, or student appreciation of the relevance of the course. However, there are only a handful of courses which incorporate all the aspects of a civic engagement course, including active learning pedagogy, close linkage between the science content and a unifying societal theme, and an extended project in which students apply their knowledge to a relevant societal problem. Examples of such courses indicate that it is possible to implement such a program in majors level courses, and that students benefit in multiple ways from the curriculum, including positive student course evaluations and high enrollments, as well as positive student comments and anecdotal reports of enhanced student attractiveness to employers because of the higher order skills gained during the projects required for the course (*15–17*).

This paper describes implementation and evaluation of a majors level chemistry course, Quantitative Analysis, taught for five years in a civic engagement format at Roosevelt University. The evaluation seeks to assess whether the civic engagement approach was successful in promoting student learning in the course, including fundamental science skills, specific content associated with the analytical chemistry, and higher order learning skills. This project also seeks to assess whether the civic engagement course had the effect of increasing students' interest in the course material, their intentions to seek further training in the sciences, their attitudes towards science, or their sense of civic engagement.

Table I. Civic Engagement Model Courses, 2001-2008

Science & Mathematics General Education Courses
Pregnancy Outcomes in American Women (2008)
Aids Research: Global Understanding & Engagement (2008)
Food for Thought (2008
The Science of Sleep (2008)
The Power of Water (2007)
Science on the Connecticut Coast (2007)
Addiction: Biology, Psychology & Society (2006)
Health and Society: Weighing In (2006)
Quantitative Literacy through Community-Based Group Projects (2006)
The Chemistry of Daily Life: Malnutrition & Diabetes (2005)
Nanotechnology (2005)
Renewable Environment: Transforming Urban Neighborhoods (2005)
Chemistry & Ethnicity: Uranium & Native Americans (2004)
Forensic Investigation: Seeking Justice Through Science (2004)
The Mathematics of Communication: Keeping Secrets (2004)
Sustainability & Human Health: A Learning Community (2004)
Brownfield Action (2003)
Chance (2003)
Nutrition and Wellness (2003)
Energy and the Environment (2002)
Biomedical Issues of HIV/AIDS (2001)
Chemistry and the Environment (2001)
1st year Seminars & Learning Communities
Slow Food (2007)
Riverscape (2005)

Continued on next page.

Table I. (Continued). Civic Engagement Model Courses, 2001-2008

Science & Mathematics General Education Courses
Coal in Appalachian Life (2004)
Environment & Disease (2003)
Global Warming (2003)
Tuberculosis (2002)
Mysteries of Migration (2001)
Science, Society & Global Catastrophes (2001)
STEM major courses
Life Science in Context: Sub-Saharan Africa and HIV/AIDS (2008)
Introductory Statistics with Community Based Projects (2008)
Ordinary Differential Equations" - Modeling in Real World Situations Computer Ethics (2006)
Chemistry & Policy: A Course Intersection (2004)
Geology and the Development of Modern Africa (2002)
Human Genetics (2002)

Implementing Civic Engagement in Analytical Chemistry

Analytical chemistry is in some ways an ideal course in which to implement civic engagement within the chemistry major. The content is inherently applied, so that there are many opportunities to link content to societal issues. Students come into the course with pre-existing knowledge and skills from general chemistry, allowing them to undertake more demanding and meaningful applications than might be possible earlier in the curriculum. Additionally, there were practical considerations specific to Roosevelt University which contributed to the decision to implement civic engagement in analytical chemistry as opposed to other chemistry courses. Since only one section of quantitative analysis is offered per year, which is always taught by the same professor, there were no issues of consistency, continuity, or course ownership. The course also needed to be updated and made more appealing to non-chemistry majors. Unfortunately, due to staffing changes as well as several years' gap between the previous course and the civic engagement course, no "before-after" course comparisons are possible between the traditional format and the civic engagement format for analytical chemistry.

Table II. Analytical Chemistry Topics and Civic Engagement Links

Lecture topic	*Analytical application*	*Civic engagement link*
Data evaluation & error analysis	Statistical significance testing in global climate change research (*20*, *21*)	Atmospheric CO_2 concentrations; Arctic sea ice cover
Calibration methods	Calibration of instruments for long term measurement series (*22*)	Quality of atmospheric CO_2 measurements
Solution properties & volumetric analysis	Titrimetric analysis of dissolved inorganic carbon in the surface ocean (*23*)	Fate of anthropogenic CO_2; declining size of the oceanic CO_2 sink
Solubility equilibria; precipitation titrations	Chloride content of waters and soils (*18*)	Irrigation; soil salinization (*24*)
Acid-base equilibria; Acid-base titrations	Carbon dioxide equilibria in the air and oceans (*25*)	Ocean acidification; coral die-off (*26*)
Coordination chemistry	EDTA titrations of metals	Environmental fate of EDTA (*27*); mobility of metals
Activity effects; simultaneous equilibria	Acid/base effects on solubility equilibria (18)	Aluminum mobilization from soils by acid rain (*28*)
Oxidation & Reduction; Electrochemistry	Dissolved oxygen; chemical oxygen demand	Eutrophication; The Gulf of Mexico dead zone (*29*)
Spectroscopy	Spectrofluorometric measurement of Hg (II) with murexide (*30*)	methylmercury toxicity; environmental mercury exposure
Separations	Separation and measurement of pharmaceuticals in wastewater (*31*)	Emerging pollutants; tertiary treatment of wastewaters

Implementing a civic engagement curriculum in analytical chemistry presented an opportunity to upgrade an outdated course, several barriers to implementation had to be overcome. These included making room in the curriculum to include societally important applications of analytical chemistry, selecting a uniting theme for the course, and identifying a meaningful laboratory project which covers the range of skills and content expected for analytical chemistry, while providing higher order research and critical thinking skills as well as a societal link. Other more general barriers were the faculty time and energy needed to redevelop a course, and logistical and financial barriers to the laboratory project, including identifying sampling equipment, and arranging for and paying for field trips. Approaches to overcoming each of these barriers to implementation are discussed below.

Table III. APHA Methods Used and Skills Taught

APHA method used	*Analytical Chemistry Experiment*	*Skills Taught*
Total and dissolved solids (*APHA 2400*)	Calibration of Volumetric Glassware [(*18*)*, lab #1*]	Calibration and use of volumetric glassware, elementary statistics
Suspended Solids (*APHA 2500*)	Gravimetric Determination of Calcium Oxalate in an impure solid [(*18*)*, #2,3*]	Filtration, drying and ignition; use of analytical balances
Chloride in water with visual and conductimetric endpoints (*APHA 4500-Cl*)	Soluble Chloride in an impure sample by precipitation titration [(*35*)*, lab #37D2*]	Preparation and standardization of solutions; titrations & titration calculations; titration errors; statistical comparison of methods;
Total, carbonate and bicarbonate alkalinity (*APHA 2320*)	Analysis of a mixture of carbonate and bicarbonate [(*18*)*, #6,7,8*]	Standard acids & bases; neutralization titrations;potentiometric titrations
Water hardness by EDTA titration (*APHA 2340*)	Calcium and Magnesium in limestone by EDTA titration [(*18*)*, #11*]	EDTA titrations; simultaneous equilibria; matrix effects; masking agents,
Nitrate by ion selective electrode (*APHA 4500-NO3*)	Ammonia in aquarium water by ion selective electrode [(*18*)*, #16*]	Potentiometry; spike recovery calculations; standard additions
Chemical oxygen demand by dichromate oxidation and colorimetric detection (*APHA 5220D*)	Spectrophotometric determination of manganese in steel [(*18*)*, #27*]	Sample digestions; matrix effects; standard addition calibration, uv/vis spectroscopy

Course Structure

Quantitative Analysis was introduced in 2004 in a civic engagement format. The 4 credit hour course consists of two 75-minute lecture periods, one 50 minute discussion period, and one 150 minute laboratory period per week over a fifteen week semester. The textbook used is Exploring Chemical Analysis (*18*). Prerequisites include College Algebra and two semesters of General Chemistry. The class is required for B.S. and B.A. chemistry majors, and is one of two courses which may be selected as the final requirement for a chemistry minor. The class is offered annually, and has run in modified format from 2004-2008, with class sizes ranging from six to seventeen students, with an average class size of 9.6 students and a total of 48 students. The distribution of majors for students enrolled in the class is 47% chemistry majors, 31% biology majors, 4% allied health majors, 4% psychology majors, and 12% other or undeclared major.

Table IV. Student Performance on ACS Analytical Chemistry Exam

Content Topic (# of questions)	*National Norm*	*C237 class*	*Performance compared to national norm*
Data Evaluation & Error Analysis (6)	58%	70%	12%
Solutions & Volumetric Analysis (6)	68%	86%	18%
Solubility & Gravimetric Analysis (4)	40%	35%	-5%
Acid-Base Chemistry (8)	57%	61%	4%
Coordination Chemistry (3)	62%	68%	7%
Redox Chemistry (4)	57%	59%	2%
Electrochemistry (5)	59%	63%	4%
Spectroscopy (7)	64%	76%	12%
Chromatography (7)	53%	51%	-2%

Lecture Implementation

The course follows a lecture format, interspersed with intervals of student group work. Each major lecture topic in the analytical chemistry course includes a civic application. Although many applications of analytical chemistry are available over a huge range of disciplines, for this course, the unifying theme is how analytical measurements of environmental quality are used to inform public policy. This theme allows for specific examples ranging from local to regional to global (*19*). Examples were taken from analytical chemistry textbooks and from the scientific literature. Whenever possible, applications were added directly to the lecture content. Table II lists analytical chemistry topics covered, the environmental application chosen and its societal and policy relevance.

To reinforce the civic engagement theme, homework assignments were modified to strengthen their relevance to the interrelated topics of analytical measurement, environmental quality and public policy. For example, an assignment to review spreadsheet functions was altered so that instead of analyzing the textbook-supplied data, students used data downloaded from a global climate change database (*32*) to practice spreadsheet entry, graphing, and elementary statistics. Students use that information to discuss how analytical measurements affect public policy towards greenhouse gases and global warming. Finally, each student compiles a portfolio of current events articles during the semester, gathered from newspapers, magazines, etc, which illustrate links between an analytical chemistry topic, an environmental or climate topic, and a public policy debate or decision. Students are required to write summaries of the news article and explain its link to course topics and to public policy. Students share their portfolio articles in discussion section. In order to make room for the civic engagement topics, several common analytical chemistry topics had to be dropped or covered in a cursory fashion in the lecture curriculum. These included calculation of titration curves for polyprotic acid/base systems, coulometry, voltammetry, detailed treatment of activity effects and simultaneous equilibria, and detailed treatment of oxidation-reduction titrations.

Laboratory Implementation

The laboratory is built around a semester-long research project in which students document how wastewater treatment plants affect water quality in the Chicago River, and whether or not the adoption of tertiary treatment at these plants would lessen their impact on water quality. To do this, students collect water samples upstream and downstream from several Chicago-area water reclamation plants which utilize either secondary or tertiary level treatment, and analyze them throughout the semester using a series of standard methods for water quality analysis (*33*). At the end of each semester, the class prepares a poster which summarizes their collective results, and statistically compares upstream and downstream concentrations of various analytes at each reclamation plant. For analytes that show significantly different concentrations upstream and downstream of a treatment plant, students compare results for the secondary and tertiary treatment plants, and use literature and internet resources to investigate whether or not addition of tertiary treatment at the treatment plant could be an effective method for remediating that substance. At the end of the poster, students must make a recommendation for whether or not specific water reclamation plants should adopt tertiary treatment as a means of improving water quality in the Chicago River system. Students present their poster at Roosevelt University's annual undergraduate research forum, and to a public audience at the Friends of the Chicago River annual student research symposium. Thus, the Chicago River project fosters a whole series of higher order skills beyond the analyses themselves, including design and implementation of a sampling scheme, consideration of quality assurance measures for samples of truly unknown composition, evaluation of results in a broader contextual setting, using analytical data to generate a policy recommendation, and scientific presentation skills. Students would not gain these higher order skills without the civic engagement class project.

The research scenario used in the Chicago River project permits selection of a wide variety of water quality analyses, allows for direct laboratory application of lecture topics, and provides students with the same fundamental laboratory skills as they would gain in a more standard section of analytical chemistry. This is illustrated in Table III, which compares a series of analytical chemistry experiments taken from current analytical chemistry textbooks, the APHA standard methods used, and the laboratory skills taught. The fundamental skills addressed by the curriculum include reading, understanding & implementing analytical methods; maintaining a laboratory notebook; calibrating volumetric glassware; preparing and standardizing solutions; conducting gravimetric and volumetric analyses and associated calculations, preparing calibration standard; conducting spectrometric analyses; using spreadsheets to process and statistically analyze data, and preparing laboratory reports. Because of the extra time needed for field sampling, class trips to a water reclamation plant and a water quality laboratory, and poster preparation, students conduct fewer analyses than they might in a non-civic engagement course. Similarly, students do not gain hands-on experience with chromatography, although it is covered in the lecture portion of the course. Students do gain extensive laboratory coverage of chromatography in the follow-up instrumental analysis course.

However, the disadvantages to the civic engagement lab are more than compensated by the benefits of adopting an over-arching research question involving local environmental samples. For example, students gain experience in representative sampling, field measurements, sample preservation and sample processing. Additionally, students follow published standard methods written for practicing analytical chemists (*33*), rather than a laboratory manual written for students. Because the standard methods are written broadly in order to apply to a wide range of water samples, students have to select among flow path options in a method, which requires them to think more deeply about the method in order in order to adapt it to their particular samples. Students also gain experience in recognizing and addressing analytical interferences, since their analytes are in a complex and unknown matrix. Students are therefore required to understand and implement procedures for method validation and quality control, and as is the case with practicing analytical chemists, they have to assess the quality of their results for samples of truly unknown composition. In order to provide some objective measure of the accuracy of their results, students download historical measurements of Chicago River water quality at their sampling locations from a US EPA website (*34*). These data also assisted students in discussing their results within a larger scientific and societal context.

In addition to these educational benefits, students were more engaged by their laboratory work because it required the analysis of meaningful, local environmental samples in a semester-long research scenario with policy implications (to adopt or not to adopt tertiary water treatment). Students took their work more seriously because they had to present it to their peers and to other science faculty at a research forum. The Chicago River project also enhanced students' awareness of environmental resources and of policy issues which affect them. Field trips to the US EPA and the Metropolitan Water Reclamation District provided students an opportunity to meet practicing environmental analytical chemists and learn about careers in that field. Finally, class visits by representatives from a local environmental group, Friends of the Chicago River, increased students' sense of community and civic engagement, and fostered stronger relationships between academia and community and civic organizations.

Evaluation of Course Modifications

Although civic engagement courses have been implemented in majors level courses at several colleges and universities, there is little published data on its effectiveness, either with respect to student learning of specific course content objectives, or student attitudes towards either science or civic engagement. Here, we present assessment data compiled over five years of the civic engagement Analytical Chemistry course. Assessment of the civic engagement curricular approach was made through on-line student surveys (Student Assessment of Learning Gains), the ACS standardized exam in analytical chemistry, as well as grade distributions and retention data.

Assessment of Content Learning

Student learning of science content was evaluated in two ways. First, all students took the American Chemical Society's standardized analytical chemistry exam as their final exam for the course, and ACS exam scores and grade distributions compiled. Second, students assessed their own learning using the web-based Student Assessment of Learning Gains (SALG) instrument. Student self assessment of learning included self-reported gains regarding lecture content objectives, laboratory content objectives, and general science content objectives.

ACS Exam Results and Grade Distributions

The ACS exam in analytical chemistry was used as the final exam for the course in all five years during which it was offered in a civic engagement format. In all, of the 48 students who enrolled in the course during this time period, 42 students, or 88%, completed the course including the ACS final. The remaining 12% of students withdrew from or failed the course without taking the final. Of students taking the ACS exam, the distribution of scores, expressed as percentiles relative to national norms, ranged from a high score of100th percentile to a low score of 9th percentile, with a class mean and median of 55th and 57th percentiles, respectively. Grade distributions for these students ranged from A to D, with a mean of grade of 2.88, which corresponds to a high C. These data show that despite some cuts to the traditional analytical chemistry lecture content required to make room for the civic engagement content of the course, students still demonstrated an acceptable level of content mastery, as measured by their performance on a nationally normed, standardized exam.

In addition to overall percentile results, ACS exams results were analyzed by student performance on particular analytical chemistry content topics, as shown in Table IV. For each major analytical topic, the national norm for questions on that topic, the percentage of C237 students responding correctly to questions on that topic, and the difference between the class and the national norm are given. Relative to national norms, C237 students did particularly well on questions relating to data evaluation, volumetric analysis and spectroscopy, all of which were well covered in both lecture and in the Chicago River lab project. In contrast, C237 students performed slightly below national norms on questions related to solubility, gravimetry and chromatography, which both received short coverage in lecture and little or no coverage in lab.

Table V. Student Self-Reported Gains on Lecture Objectives[a]

How confident are you in your ability to:	*Pre*	*Post*	*Gain*
Understand complex ions and EDTA titrations	2.1±0.5	3.9±0.6	1.8
Understand electrochemistry, redox titrations and potentiometry	2.3±0.5	3.6±0.5	1.3
Understand calibration and standardization techniques	3.0±0.4	4.2±0.4	1.2
Identify steps in the analytical process	3.1±0.5	4.3±0.3	1.1
Classify sources of error and statistically analyze data	3.1±0.6	4.1±0.4	1.0
Understand activity effects and simultaneous equilibria	2.5±0.6	3.5±0.7	1.0
Understand spectrophotometric theory and instruments	3.0±0.5	3.7±0.7	0.7
Understand solubility and precipitation titrations	3.0±0.6	3.7±0.4	0.7
Understand acid/base equilibria and neutralization titrations	3.1±0.5	3.8±0.6	0.7
Understand chromatographic theory and instruments	2.9±0.6	3.4±0.7	0.6
All lecture objectives	2.8±0.5	3.8±0.5	1.0

[a] Scale: 1 = not at all confident, 2 = a little bit confident, 3=moderately confident, 4 = very confident, 5=extremely confident. Pooled responses of n= 23 students from course years 2006-2008

Grade distributions show that 85% of students passed the course with an A, B or C grade acceptable for credit in the major, while15% received grades or D or F or withdrew from the course. Data are not readily available on student success rates in analytical chemistry courses nationally or at other institutions. However, the percent of students receiving grades of W, D or F in other 200-level chemistry courses at our institution over the same period of time hovers between 30-35%. None of the other 200-level chemistry courses use a civic engagement approach. Thus, the civic engagement analytical chemistry course had a higher student pass rate relative to other required chemistry classes at a comparable level of difficulty. However, no conclusions can be drawn directly about whether the civic engagement format contributed to the higher student success rate, due to a large number of uncontrolled factors, such as differences in course content, prerequisites, percentage of chemistry vs non-chemistry majors, and required vs elective course status.

Table VI. Student Self-Reported Gains on Laboratory Objectives[a]

How confident are you in your ability to:	*Pre*	*Post*	*Gain*
Prepare and standardize solutions	3.1±0.7	4.5±0.3	1.4
Assess the quality of analytical results	2.5±0.6	3.9±0.4	1.4
Recognize and overcome matrix effects	2.2±0.5	3.6±0.6	1.4
Calibrate and use volumetric glassware	3.1±0.6	4.4±0.4	1.3
Obtain and process representative samples	2.8±0.6	4.2±0.5	1.3
Perform titrations and associated calculations	3.2±0.6	4.5±0.4	1.3
Accurately weigh both by tare and by difference	3.2±0.5	4.4±0.4	1.3
Implement common quality control procedures	2.9±0.6	4.0±0.5	1.2
Discuss analytical results in broader contexts	2.8±0.6	3.9±0.4	1.1
Perform spectrophotometric analyses	3.0±0.7	3.9±0.5	0.9
Keep a detailed laboratory notebook	3.6±0.6	4.4±0.5	0.8
Follow published analytical methods	3.2±0.5	3.9±0.4	0.7
Use spreadsheets to process and analyze data	3.5±0.6	4.1±0.5	0.6
Write laboratory reports following standard format	3.5±0.5	4.0±0.6	0.5
All Laboratory Objectives	3.0±0.6	4.1±0.5	1.1

[a] 1 = not at all confident, 2 = a little bit confident, 3=moderately confident, 4 = very confident, 5=extremely confident.

Student Survey of Learning Gains

A web-administered survey, the Student Assessment of Learning Gains, or SALG, was used to assess students' self-reported learning gains on key lecture, laboratory, and general science learning objectives, as well as students' self-reported interest in science and in civic issues. Most of the questions on the SALG are multiple choice response questions that use a five-point scale to permit quantitative analysis of responses. No survey was given in the 2004 or 2005 course offerings. For the 2006, 2007 and 2008 offerings, the survey was administered in the first week of the course (pretest), and again in the final week of the course (post-test). Student login to the website was authenticated by student id numbers in order to confirm participation in the survey and to prevent duplicate responses, however, individual students' answers were not traceable to their login id in order to ensure the anonymity of student responses. The SALG website allows for anonymous responses of each individual to be compared between pre-course and post-course surveys. The difference in score between post-test and pre-test corresponds to that student's gain on a particular topic in the course. Participation in the survey was entirely voluntary and did not affect students' course grade in any way. Over the three years that the survey was administered, a total of 23 students of 30 possible students completed the survey, for a 77% participation rate. For questions involving lecture, laboratory and general science objectives, students were polled as to their self-reported confidence in their mastery of that skill on a scale of 1 (not at all confident) to 5 (very confident). For questions involving interest, students were polled on a scale of 1 (not at all interested) to 5 (very interested). On average, students took about 7 minutes to complete 67 survey questions divided into 5 categories. For each survey question, the mean pre and post responses and the one-sigma standard deviation of the mean were calculated. Means and uncertainties were compared using a comparison of means test to determine whether the gains reported were significant at the 95% confidence level.

Learning Gains on Lecture Objectives

Table V shows students' self-reported average pre-course and post-course confidence, and calculated learning gains, for ten major lecture objectives, ordered from greatest gain to smallest gain. These are pooled results from 2005-2008, and represent 23 total students. Prior to the course, student's average self-reported confidence ranged from a low of 2.1 for understanding of complex ions and EDTA titrations to a high of 3.1 for several topics, including the analytical process, statistical analysis of data, and acid/base equilibria. On average, student confidence in their understanding of all lecture objectives prior to the start of class was 2.8, falling between "a little bit confident" and "moderately confident". After completion of the course, student's average confidence in their understanding of the course topics ranged from a low of 3.4 for chromatography to a high of 4.3 for the analytical process, and averaged 3.8 on all lecture topics. The average gain of 1.0 is significant at the 95% confidence level. Students reported the largest gains in their understanding of complex ions and EDTA titrations (1.8), and the lowest gains on chromatography (0.6), which was covered only briefly at the end of the course. There was a weak negative correlation between the average gain and the average pre-course confidence in a topic ($y = -0.73x + 3.1$; $R^2 = .53$), which might be expected given that the better a student's understanding of a topic based on previous coursework, the less the learning gain on the topic during the follow-up course.

Table VII. Student Self-Reported Gains on General Science Objectives[a]

How confident are you in your ability to:	*Pre*	*Post*	*Gain*
Obtain scientific data in a laboratory or field setting	3.2±0.3	4.1±0.3	0.9±0.4
Understand mathematical and statistical formulas	2.8±0.5	3.7±0.4	0.9±0.6
Write reports using scientific data as evidence	3.2±0.4	3.9±0.3	0.7±0.5
Give a presentation about a science topic to your class	2.7±0.5	3.4±0.4	0.7±0.6
Pose questions that can be addressed with scientific evidence	3.2±0.3	3.8±0.3	0.6±0.5
Understand the science content of this course.	3.3±0.5	3.9±0.3	0.6±0.6
Understand how scientific research is carried out	3.5±0.2	4.1±0.3	0.6±0.4
Understand and summarize scientific articles	3.0±0.4	3.6±0.4	0.6±0.6
Think critically about scientific findings I read about in the media	3.2±0.4	3.8±0.4	0.6±0.6
Understand scientific processes behind issues in the media.	2.9±0.3	3.4±0.4	0.5±0.5
Determine what is -- and is not -- valid scientific evidence	3.1±0.4	3.6±0.3	0.5±0.5
Find scientific journal articles using library/internet databases	3.4±0.3	3.8±0.3	0.4±0.5
Determine the difference between science and "pseudo-science"	2.9±0.4	3.1±0.3	0.2±0.5
Discuss scientific concepts with my friends or family	3.4±0.4	3.6±0.3	0.2±0.5
Interpret tables and graphs	3.7±0.3	3.9±0.4	0.2±0.5
Search for relevant data to answer a question	3.1±0.3	3.2±0.4	0.1±0.5
Make an argument using scientific evidence	3.4±0.5	3.4±0.5	0.0±0.7
All General Science Objectives	3.2±0.4	3.7±0.4	0.5±0.5

[a] (1 = not at all confident, 2 = a little bit confident, 3=moderately confident, 4 = very confident, 5=extremely confident)

Table VIII. Student Self-Reported Gains in Integration of Knowledge[a]

On a scale of 1 to 5, how often do you:	*Pre*	*Post*	*Gain*
Connect key ideas you learn in classes with other knowledge	3.7±0.4	4.9±0.1	1.2±0.4
Apply what you learn in your classes to other situations	3.7±0.4	5.0±0.3	1.3±0.5
Use systematic reasoning in your approach to problems	3.4±0.3	5.0±0.3	1.6±0.5
Critically analyze data and arguments in your daily life	3.6±0.4	5.0±0.3	1.4±0.5
All questions on integration of knowledge	3.6±0.4	5.0±0.3	1.4±0.5

[a] 1 = almost never, 2=occasionally, 3=somewhat often, 4=fairly often, 5=very often

Learning Gains in Laboratory Objectives

Table VI shows students' pre- and post-course confidence and learning gains for fourteen laboratory objectives, ordered from greatest to smallest gain. These pooled results represent 23 students in years 2005-2008. Prior to the course, student's confidence ranged from a low of 2.2 for recognizing and overcoming matrix effects to a high of 3.6 for maintaining a lab notebook, and averaged 3.0, or "moderately confident" on all topics. After completion of the course, student's confidence in their understanding of the course topics ranged from a low of 3.6 for matrix effects to a high of 4.5 for preparing and standardizing solutions and for performing titrations, and on average, increased to 4.1, or very confident. The average gain of 1.1 is significant at the 95% confidence level. Students reported the largest gains in preparing solutions, assessing results, and in matrix effects (1.4 for each), and the lowest gains for using spreadsheets and for writing lab reports (0.5 and 0.6, respectively). As with the lecture objectives, there was a weak negative correlation between the average gain and the average pre-course confidence in a topic ($y = -0.57x + 2.8$; $R^2 = .47$), which helps to explain the weak gains on spreadsheets and writing reports, despite the fact that they were performed on a weekly basis. Students' initial confidence in these skills was already high, indicating that they already brought these skills to the laboratory portion of the course, so that the course led to only modest gains in these pre-existing skills.

Several objectives that were directly addressed by the civic engagement format of the course showed among the strongest laboratory learning gains. These included recognizing and overcoming the matrix effects associated with the complex environmental samples (1.4±0.8), assessing the quality of analytical results (1.4±0.7), obtaining and processing representative environmental samples (gain of 1.3 ±0.7), and discussing analytical results in a broader context (1.1±0.7). These higher-order learning skills would not have been addressed by analysis of a series of instructor-generated synthetic unknowns. Gains in these areas indicate the value of the civic engagement laboratory in fostering higher-order analytical skills than might otherwise be possible in previous versions of the course.

Correlation between Exam Scores and Self-Reported Learning

Students' self-reported understanding of various lecture and laboratory learning objectives was also compared to their performance on ACS exam questions testing those topics. Each of the ten major content areas of the ACS exam was paired with the lecture or lab objective that most closely matched that topic. Students' average self-reported understanding of the topic, as reported in the post-course survey, was plotted against the students average score on the same topic, reported relative to national student scores on the same topic. For example, on average, students' self-reported confidence in their ability to "classify sources of error and perform statistical analysis of data" was 4.07, while their average percent correct on all ACS exam section covering data evaluation and error analysis" was 12% above the national norm for percentage correct on those questions.

As shown in Figure 1, there was a moderate positive correlation of 3.45 between students' average self-reported learning gain for a topic and students scores on that topic, with a correlation coefficient of 0.65. Although student surveys of learning obviously cannot replace quantitative measures of performance such as content exams, the correlation between learning survey and exam performance confirms the value of student surveys as a secondary measure of student learning.

Learning Gains in General Science Objectives

The learning objectives for lecture and laboratory listed above concern very specific analytical chemistry content. In addition to these course-specific objectives, students were also surveyed with respect to their gains on a series of more general objectives related to overall science literacy. Results of the SALG survey of general science objectives are given in Table VII. Prior to the course, students' self-reported scores on general science objectives ranged from a high of 3.7 for "Interpreting tables and graphs" to a low of 2.9 for "Understanding the scientific processes behind issues in the media". The average pre-course score of 3.2 on general science objectives was slightly higher than the average pre-course score for lecture and lab objectives, which averaged 2.8 and 3.0 respectively. The gains reported by the end of the semester were in general smaller, and although positive, the average gain of 0.5 ± 0.5 was not statistically significant. As before, there was a negative correlation between the average gain and the average pre-course confidence in a topic ($y = -0.40x + 1.8$; $R^2 = 0.16$), but the relationship was much weaker, with a correlation coefficient of only 0.16. The largest gains were reported for general science objectives which closely matched specific course objectives, for example, obtaining scientific data in a laboratory or field setting (0.9 ± 0.4), understanding mathematical and statistical formulas (0.9

± 0.6), writing reports using scientific data as evidence (0.7 ± 0.5), and giving presentations on a science topic (0.7 ± 0.6).

Learning Gains in Integration of Knowledge

In addition to general and specific learning objectives, students were polled on how well they felt they integrated their learning with other classes and in other areas of their lives. This section of the SALG survey was added in 2008, so results are only available for the 2008 offering of the course. However, as shown in Table VIII, those results indicate that the civic engagement analytical chemistry course resulted in strong gains in every category of knowledge integration, including connecting coursework to other knowledge, applying coursework, using systematic reasoning, and critically analyzing data and information in daily life. On average, for all questions of integration of knowledge, students reported gains of 1.4 ± 0.5 following completion of the course.

These strong gains in integration of knowledge were also reflected in student comments at the end of the course,

> *"This course placed organic chemistry terms more in perspective. Not only did it provide a better understanding for other chemistry terms I've learned over the years, it was able to answer some questions that I had over the years about the advantages of some chemical analysis."*

> *"I liked how this class was related to my statistics class. Having both classes helped me in both classes."*

> *"I liked that the instructor applied what we were learning to real world applications."*

> *"I really liked the course. I liked the lab and how we analyzed water we see everyday in Chicago."*

Such comments, as well as student gains in the integration of knowledge section of the SALG survey, showed that students found their learning in this course carried over to other coursework, and that they appreciated the opportunity to apply their learning in the Chicago River laboratory project.

Assessment of Student Attitudes

In addition to improving learning in the sciences, two major goals of the SENCER project are to increase student interest in the sciences, and to increase students' sense of civic engagement. Students were surveyed with respect to their attitudes towards science and their level of civic engagement, in order to determine whether this civic engagement course resulted in gains, either in students' interest in science or in students' sense of civic engagement.

Gains in Science Interest

Probably because C237 is populated primarily by science majors, initial pre-course surveys indicated students entered the class already with moderate to very high response to all science interest questions. As shown in Table IX, in the pre-course survey, students reported the highest levels of interest in majoring in the sciences (4.5±0.3), exploring careers in the sciences (4.5±0.3), and taking additional science courses (4.3±0.2), and the lowest interest in teaching science (2.4±0.7), joining a science club or organization (2.9±0.6), and reading about the relationship between science and civic issues (3.1±0.5). Overall, the pre-course response to all science interest questions averaged 3.5 ±0.5, the post-course response averaged 3.8±0.4. The average gain on all science interest question of 0.3±0.6 was positive but not statistically. One unanticipated result of the class were the gains observed in students interested in teaching science, which had the largest gain of all the science interest questions, although it also had the largest variation in responses.

Table IX. Self-Reported Gains in Science Interest

On a scale of 1 to 5, how interested are you in:	*Pre*	*Post*	*Gain*
Teaching science	2.4±0.7	3.0±0.8	0.6±1.1
Reading about science and its relation to civic issues	3.1±0.5	3.5±0.3	0.5±0.5
Joining a science club or organization	2.9±0.6	3.2±0.5	0.4±0.8
Attending professional school in a science-related field	3.6±0.4	3.9±0.4	0.3±0.6
Discussing science with friends or family	3.3±0.5	3.5±0.3	0.2±0.6
Reading articles about science in magazines, journals or on the internet	3.3±0.3	3.5±0.3	0.2±0.5
Exploring career opportunities in science	4.5±0.3	4.7±0.3	0.2±0.4
Majoring in a science-related field	4.5±0.3	4.6±0.3	0.1±0.4
Attending graduate school in a science-related field	3.6±0.5	3.7±0.5	0.1±0.8
Taking additional science courses	4.3±0.2	4.3±0.3	0.0±0.3
All questions regarding science interest	3.5±0.5	3.8±0.4	0.3±0.6

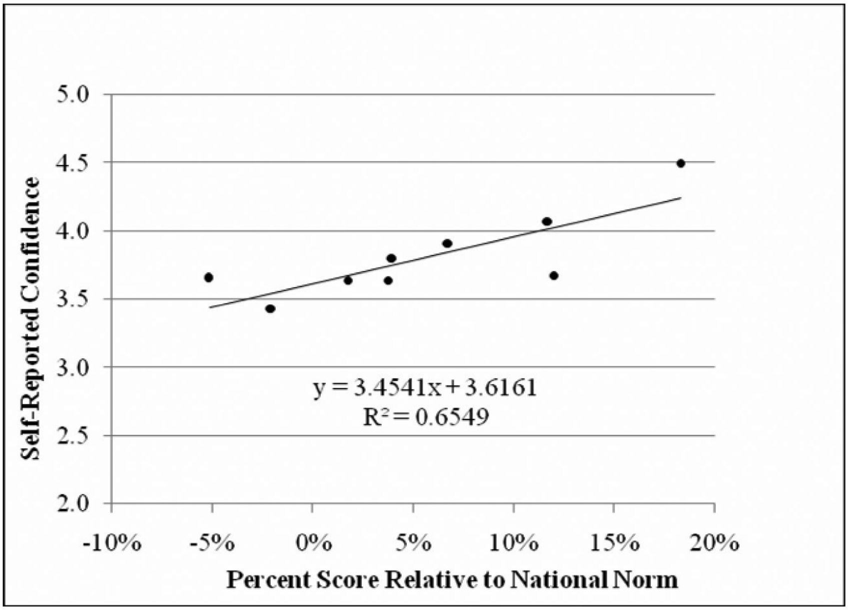

Figure 1. Correlation between self-reported learning gain and exam scores

Gains in Civic Engagement

Initial pre-course survey results showed that at the beginning of the course, students had relatively low levels of civic engagement. As shown in Table X, the highest areas of initial civic engagement were in voting in elections (3.8 ± 0.5) and reading newspapers or news magazines (3.5 ± 0.3). , with an average interest rating of 2.6 for the activities mentioned in the survey. Participation in the course resulted in gains in all areas of civic engagement. Areas of largest gains included attending meetings, rallies or protests (1.0±0.5), reading newspapers or news magazines (0.9±0.4), voting (0.6±0.6), and debating or commenting on issues (0.6±0.7), as well as smaller gains in other areas. The average self-reported gain on civic engagement questions was 0.6 ± 0.3.

Table X. Self-Reported Gains in Civic Engagement[a]

On a scale of 1 to 5, how interested are you in:	*Pre*	*Post*	*Gain*
Attending a meeting, rally, or protest about a civic or political issue	2.0±0.3	3.0±0.4	1.0±0.5
Reading a newspaper or news magazine not required for class	3.5±0.3	4.4±0.3	0.9±0.4
Voting in elections	3.8±0.5	4.4±0.4	0.6±0.6

Continued on next page.

Table X. (Continued). Self-Reported Gains in Civic Engagement[a]

On a scale of 1 to 5, how interested are you in:	*Pre*	*Post*	*Gain*
Debating or offering public comment on a civic or political issue	2.1±0.4	2.7±0.6	0.6±0.7
Discussing a civic or political issue with friends	2.5±0.4	3.0±0.4	0.5±0.6
Writing or emailing a public official about a civic or political issue	2.4±0.6	2.9±0.3	0.5±0.7
Joining or taking an internship at a civic or political organization	2.4±0.4	2.9±0.6	0.5±0.7
Taking part in a one-time civic event such as walk-a-thons	2.8±0.3	3.3±0.5	0.5±0.6
Talking with a public official about a civic or political issue.	2.4±0.5	2.7±0.5	0.3±0.7
Writing a letter to the editor about a civic or political issue	2.0±0.4	2.1±0.4	0.1±0.6
All Civic Engagement Questions	2.6±0.2	3.1±0.2	0.6±0.3

[a] 1 = not at all interested, 2 = a little bit interested, 3=moderately interested, 4 = very interested, 5=extremely interested

Conclusions and Future Work

A civic engagement approach was successfully implemented for five years in a majors-level analytical chemistry course. Class meetings follow a format of lectures supplemented with civic engagement threads. Homework assignments were altered to reinforce the civic engagement ideas, and students were assigned additional current events readings. To make room for the civic engagement content, several advanced topics were dropped from the curriculum, coverage of other topics was reduced, and weekly in class quizzes were replaced with graded homework assignments in order to make more room for discussion of applications. The laboratory consisted of a semester-long environmental sampling and water quality analysis project

Assessment of the civic engagement approach was made through standardized exams, grade distributions, retention data, and student surveys. Five years of standardized exam scores indicate satisfactory understanding of core majors chemistry content relative to national norms. Grade distribution and retention data indicate 85% of students enrolling in the course pass with grades of A, B or C, while 15% receive grades of D or F or withdraw from the course. This student success rate compares favorably with other chemistry courses at the same level at our institution. However, due to lack of control sections, it is not possible to say whether the civic engagement format is more effective than a traditional course format, either with respect to student performance on standardized exams or in student pass rates in the course overall.

Three years of student survey results indicate strong gains in self-reported learning on lecture objectives (1.0 ± 0.8) and laboratory objectives (1.1± 0.7) specific to the course. Self-reported gains on specific learning objectives correlated with performance on subsections of the standardized final exam. This result reinforces the validity of student surveys as a means of assessing student learning. Students reported strong gains in integration of knowledge (1.4 ± 0.5), as well as smaller gains on general science objectives (0.5 ± 0.5). The small gains on general science objectives may have been due in part to higher pre-course levels proficiency in general science skills than in specific analytical chemistry course objectives among these predominantly 2nd and 3rd year biology and chemistry majors. Students also reported modest increases in their level of civic engagement (0.6± 0.3). Students reported only small gains in their interest in science (0.3 ± 0.6), but again, these small gains may be due to the high initial levels of science interest among these primarily science majors. One unanticipated outcome of the course was that, in every year in which SALG results were available, interest in teaching showed consistently strong gains relative to other categories of science interest. Student comments towards the course and especially towards the laboratory format were very positive. Overall, the experiment in implementing a civic engagement format for this majors level analytical chemistry course was successful. As a consequence, civic engagement sections are being planned for the general chemistry sequence, and upper division instrumental analysis in order to broaden our institution's use of this successful course format.

Acknowledgments

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Chapter 7

Ground Level Ozone in Newton County, GA: A SENCER Model for Introductory Chemistry

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In an effort to implement a SENCER module into a first semester general chemistry course, a long-term air quality study has been initiated at Oxford College. This study, conducted in introductory chemistry courses for both science majors and non-science majors, is focused on the measurement of ground level ozone. As part of this project, students have created ozone detectors, helped design a long-term study that monitors local ground-level ozone, collected ground-level ozone concentration data at Oxford College, and created written reports that summarize both the general background information related to ground level ozone, as well as the data collected in class. This work, as well as preliminary assessment of the impact of this project on student attitudes and learning gains is described.

Introduction

During the early part of my professional career as an educator, my philosophy of teaching focused on demonstrating my enthusiasm for chemistry to the students. The thought was that I could transfer my joy of the subject to the learner by overwhelming force. If they saw how much I loved chemistry and realized how "cool" it was, how could they not become enchanted? Perhaps in a way this may have worked; I believe I was considered a popular teacher by most of the students and they routinely did quite well on the end-of-course exams. However, after a couple of years passed by, I sensed that small groups of students did not buy into my excitement. This really disappointed me. If some of my students were not learning to love chemistry, or at least begin to appreciate it, then what were they taking away from my class?

My philosophy of teaching shifted then to not only demonstrating how interesting chemistry was, but began to also concentrate on having my course provide a set of skills that my students could use later in their lives. Even though they likely would not remember how to draw chemical structures or calculate the theoretical yield of a chemical reaction, perhaps they would take with them the ability to design a sound experiment or correctly analyze and interpret data. Therefore, even if a student did not develop a passion for the subject matter, at least s/he would gain some practical skills in my class. This approach helped provide a more meaningful reason to study chemistry, but I felt the general chemistry curriculum remained an abstract set of information for most students. Something was still missing.

When I arrived at Oxford for my first full time position in higher education, I was quickly made aware of how I could make chemistry real and not remote to my students' lives: the implementation of SENCER (Science Education through New Civic Engagements and Responsibilities). [For more information about SENCER, the reader is referred to www.sencer.net]. One of my colleagues in the chemistry department had developed a lab module for the non-majors general chemistry course that required the students to complete a water quality study, and I gladly adopted this lab module into my non-majors introductory chemistry courses (*1*). We did these lab activities in an effort to provide a more meaningful reason for learning chemistry, and this SENCER project was indeed quite successful in making chemistry relevant to our students' lives and seemed to stimulate their intellectual curiosity much more than our traditional laboratories. In addition, the literature describing these types of projects suggested that though these activities do not necessarily "improve the ability of students to recall facts, it likely increases the ability to use evidence to support claims or to identify and solve complex problems (*2*)." It seemed that I had finally found that missing piece to my teaching philosophy.

However, there were some limitations to the water quality study. Most of the water quality testing required the use of manufactured kits which did not clearly demonstrate the actual chemistry involved in the test, there was still some disconnection between the water quality at a local stream and the effect this might have on our students' drinking water, and I was not sure this approach could easily be used in an introductory course for chemistry majors.

In an effort to address these problems, I began to think about how I could refine the project in order to "SENCER-ize" my general chemistry courses for science majors. Luckily I stumbled across a paper by J.V. Seeley which described a simple method for measuring ground level ozone, the major component of photochemical smog (*3*). I felt air quality was a problem that had a much more direct impact on the students (we could measure the quality of the air they actually breathed), and the method of detection reported by Seeley required the students to use many of the chemistry concepts and skills learned in an introductory course. I decided this would be a convenient way to incorporate the SENCER ideals into both majors and non-majors general chemistry courses.

I describe here a summary of how air quality has been used to frame the learning goals and outcomes in my general chemistry course for both majors and non-majors, an initial qualitative assessment of this program, and how it has impacted student learning and attitudes in my general chemistry courses.

SENCER-izing General Chemistry

One of the arguments I have heard against implementing SENCER in courses intended for science majors is that incorporating a new project related to an unsolved civic issue will infringe upon the successful completion of the canonical course content. The appeal to framing the curricular content of our first semester general chemistry course around the issue of air quality lies in the fact the method reported by Seeley requires the students to apply most of the major concepts covered in this course. Table I summarizes the major concepts covered in our traditional general chemistry, those covered in our SENCER version of general chemistry, and those required to understand the concept of ground level ozone and how to complete the measurement of its concentration.

It is clear that course content is not sacrificed, at least given the manner in which we teach general chemistry at Oxford College. The only material that is not covered in the air quality version of our course is the unit on organic nomenclature. This is a small sacrifice, as this is often not covered in our traditional course due to time constraints, plus this is material that will be thoroughly covered in more advanced chemistry courses. I also note the fact that almost all of the major concepts in the course are required to complete the ground level ozone study. The unit on thermochemistry is perhaps the farthest removed from the issue of air quality, but even this can be loosely tied to the ground level ozone project as one of the important chemical precursors to ground level ozone is produced in combustion reactions. [The formation of ground level ozone is dependent on the presence of nitrogen oxide compounds (NO_x), which are primarily emitted from automobiles and fossil fuel combustion power plants. There are a variety of resources that describe in detail the formation of ground level ozone, but the reader may want to consult the reference book, *Encyclopedia of global change: environmental change and human society* (Andrew Goudie, editor, 2002, Oxford University Press, New York, New York) as a starting point.] I will not elaborate further on the details of how the concepts in this course are needed to complete the ground level ozone project, but will note that the report by Seeley, *et al.* will provide the reader with a nice summary of most of these topics. [The journal article by Seeley, *et al.* gives a detailed description of the aqueous chemical reactions involved in measuring ground level ozone, how standard solutions are prepared and used to determine the amount of ozone detected, and how the ideal gas equation is used to calculate the moles of air sampled.]

In order to frame the course around the issue of air quality, a problem-based case study was done the first week of class. This case study was centered around a scenario in which someone blames their breathing problems on ground level ozone. The students were required to identify the major issues in the case and

Table I. Major concepts covered in the traditional and air quality version of general chemistry, and those required to understand and calculate ground level ozone. General chemistry concepts that are not covered in the ground level ozone project are shown in bold. General chemistry concepts that are included in the traditional course but not in the air quality course are shown in italics

Traditional Course	*SENCER Course*	*Ground Level Ozone Project*
-measurement/data analysis	-measurement/data analysis	-measurement/data analysis
-atomic structure	-atomic structure	-atomic structure
-chemical bonding	-chemical bonding	-chemical bonding
-chemical reactions	-chemical reactions	-chemical reactions
-stoichiometry	-stoichiometry	-stoichiometry
-aqueous solutions	-aqueous solutions	-aqueous solutions
-gas laws	-gas laws	-gas laws
-intermolecular forces	-intermolecular forces	-intermolecular forces
-thermochemistry	**-thermochemistry**	
-*organic nomenclature*		

generate questions that needed to be answered in order to resolve the case. These questions were then documented, and acted as the content learning goals for the remainder of the semester. As the semester proceeded, the students were reminded about how each topic related to the problem of ground level ozone and how the specific content for each unit allowed them to answer some of the questions generated in the case study. At the end of the semester, three weeks were devoted to the problem of ground level ozone. The students completed research on the background information related to how ground level ozone forms, why it is a potential public health hazard, and how we were to measure it in lab. [Though few changes in the content of the lecture portion of the course were required, more significant changes in the lab schedule were needed to accommodate the ground level ozone measurement lab activities. In order to implement this project, the reader would need to consider that some labs may need to be eliminated.] We also did three labs where the students actually measured the concentration of ground level ozone on campus, and then all of the background information and new data were analyzed and summarized in a written report.

Anecdotally, I have receive extremely positive feedback from the students, and representative comments from student reflective statements indicate that using this approach has been an effective way to engage the students in learning science (see Table II). Almost by consensus, comments indicate that this project was successful in helping the students achieve the course learning goals and a clear connection between chemistry and the students' lives has been made.

Initial Assessment

Overall, the SENCER-inspired air quality project seemed to have a positive impact on perceived student learning, on student attitudes towards science, and on student confidence in relating how science can be used to solve social issues. The comparison of pre- and post-course surveys indicates that the air quality SENCER module had an appreciably positive impact on the students' perceived interest in discussing chemistry, and perceived confidence in solving problems, designing lab experiments, and understanding how science can be used to solve societal issues/problems. Gains were made in both the majors and non-majors courses, apparent by the increase in the average positive response on the post-course survey. There was an increase in the average response of at least 0.50 by the students in the majors course for the four selected questions, and the students maid particularly high gains in their confidence in solving problems and using science to solve societal problems (an increase in the average response was 0.80 and 0.64 for these two questions respectively; see Table III). The students in the non-majors course also made gains, as evidenced by an increase in the average response of at least 0.70 in three of the four questions. These students made particularly large gains in their confidence to design lab experiments and their understanding of how science can solve societal problems (an increase in the average for these two questions was 1.01 and 1.21 respectively; see Table III). It is also noted that a large number of students in both courses made at least some gains, as at least 55% of the students in the majors class reported gains in all four questions (70% reported gains in their ability to problem solve). The gains in the non-majors course were not quite as significant, as only 43% of the students reported gains in problem solving and in their understanding of how science can be used to solve societal problems. However, 64% of the students reported gains in their interest in discussing chemistry concepts and 78% reported gains in designing lab experiments (see Table IV).

Future work will involve doing a more rigorous statistical analysis of the current, and subsequent survey data, as well as evaluating the results of American Chemical Society (ACS) end-of-course examinations for students taking general chemistry for science majors. The performance of our students will be compared to the at-large pool of ACS exam scores, and it is the hope that these future data will indicate that teaching the first semester general chemistry course with the air quality SENCER module does not dilute the content covered in the course. In fact, it is hypothesized this approach will reinforce the content.

Table II. Representative comments from student reflective statements concerning the effectiveness of using ground level ozone as a central theme in general chemistry

Positive Remarks

-"I think the ozone project was very helpful in completing the goals of this course. The ozone project gives purpose to almost all of the activities done in the class."

-"This project was helpful in helping achieve the general course goals since it required one to learn the basics of chemistry and perceive its relevance to real world situations."

-"I enjoyed this project and I think that it has helped me to understand the importance of chemistry."

-" The ozone study brought chemistry to life for me."

-"This project was something completely different from what I covered in AP chemistry, and allowed me to apply the chemistry knowledge to a completely new area."

-"…every skill we gained throughout the year was put to the test in the calculations to find the concentration of ground level ozone."

-"I do not see how a class period that does not have to do this project will be able to understand why chemistry is relevant to their life the way we do now."

Criticisms

-"I wish there was a way to do the project at the beginning; I know it's necessary to have all of the skills and understanding that is learned throughout the semester, but maybe seeing and getting the big picture and then working backwards toward a complete understanding of the topics would help."

-"I would have felt more satisfaction with the project had I been able to see the fruits of our labor put to use in some actual change in the local community."

Conclusion

I have described here a way to teach general chemistry for majors and non-majors through the unsolved problem of air quality. This has enabled me to make a strong connection between science and the students' lives, without sacrificing important curricular components that teach chemistry concepts needed for future courses. In addition, this approach has allowed me to teach non-majors most of the topics covered in the major's course (unlike many "science appreciation" courses). Incorporating the SENCER ideals into my introductory chemistry courses has allowed me to not only help develop the critical thinking and problem solving skills in my students, but it has allowed me to clearly demonstrate to my students why they have a vested interest in learning chemistry and contributed to increasing the students' interest in science.

Results from pre- and post-course surveys, as well as free response reflective statements indicate that students feel they have achieved the course goals and made gains in acquiring new skills, particularly problem solving, experimental design, and using scientific knowledge to solve social problems. Given these outcomes, I feel confident that this approach will continue to be an effective approach to teaching general chemistry for both science majors and non-majors,

Table III. Results from selected survey questions, and representative comments from student reflective statements concerning course outcomes and the effectiveness of the SENCER module. Responses from the survey are given as the average value of the responses from a 1-5 Likert scale, along with the number of students who responded 4 (a lot) or 5 (a great deal) per total number of student respondents (given in parentheses)

	Majors	*Non-majors*
Pre-Course Question		
1. I am interested in discussing chemistry with friends or family.	3.10 (7/20)	3.0 (7/18)
2. I am confident I can solve problems.	3.20 (9/20)	3.33 (8/18)
3. I am confident I can design lab experiments.	3.20 (9/20)	2.78 (4/18)
4. I am confident I can understand how science can be used to help solve societal problems/issues.	3.16 (7/20)	2.65 (3/18)
Post-Course Question		
1. I think I will carry with me the ability to discuss chemistry concepts with me the ability to discuss chemistry concepts with peers and others.	3.60 (12/20)	3.71 (9/14)
2. This course has added to my skills in problem solving.	4.0 (14/20)	3.5 (7/14)
3. I am confident I can understand how scientific experiments are designed.	3.70 (13/20)	3.79 (9/14)
4. I am confident I can understand how scientific knowledge can be used to help address societal problems.	3.8 (15/20)	3.86 (8/14)

Table IV. The number of students who made gains in questions 1-4 (the number of students who reported some improvement from the pre-course question on the post-course question is reported)

Question	*Made gains (majors)*	*Made gains (Non-majors)*
1.	11/20 (55%)	9/14 (64%)
2.	14/20 (70%)	6/14 (43%)
3.	13/20 (65%)	11/14 (78%)
4.	12/20 (60)	6/14 (43%)

and that educators in all fields of science should consider teaching their introductory courses using the SENCER model.

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Chapter 8

Studying the Redevelopment of a Superfund Site: An Integrated General Science Curriculum Paying Added Dividends

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Abstract

A new general education science course on the redevelopment of Superfund sites integrated environmental risk assessment and basic chemical concepts. The infusion of civic engagement allowed the curriculum to be explicit in contributing to the College's outreach mission and benefits the students who clearly observe the relevance of the chemical concepts. Using a learning community approach, chemistry and sociology faculty contributed to this curriculum, initially. The field sampling laboratory experiments were central to the course content and civic engagement. The innovative curriculum gained external support yielding newer instrumentation for the Chemistry Department and facilitated further development of civic engagement in other chemistry major courses. The civic engagement requires diligent extra efforts by the faculty, yet yielded numerous benefits for the students, faculty, the community, and College.

Introduction

Adding Civic Engagement to a Chemistry curriculum already crowded with content and new technological advances may appear ridiculous to some faculty. Yet, the outcome of our students learning to become informed members of the general public on issues where science can provide useful insights is a benefit to our society. As educators, we want students to learn some specific content and integrate their learning with skills that will allow them to continue learning after taking our courses. At many colleges and universities, the general education science requirement is a single survey course. Having science education and civic engagement linked provides students the opportunity to retain more general knowledge of science.

The Science Education for New Civic Engagement and Responsibilities (SENCER) project works to improve science education through exploring civic issues where science is a critical element. In a Journal of Chemical Education article, Cathe Middlecamp and co-authors clearly outline the ideals of the project and a number of innovative courses that have been developed since its inception (*1*). Following the work of other SENCER model developers in 2002, a faculty team at Saint Mary's College created a pair of courses, to function as a learning community. The two courses were thematically linked to a societal issue, Superfund site redevelopment. A number of SENCER models focus on environmental issues including one created by Cathe Middlecamp (*2*). This book chapter provides some background on our learning community which was titled Renewable Environments Transforming: Urban Neighborhoods or RETUrN (*3*). This learning community includes a general education science course developed in the Chemistry Department that is linked to a sociology course. This learning community represents a true collaboration as both the chemical and sociological perspectives were utilized throughout the joint study of the redevelopment of a local Superfund site. The Superfund site is a former naval base in the region which closed under the base realignment and closure (BRAC) process. Since base closures have occurred throughout the United States, our linked courses are a suitable template for many parts of the country. Furthermore this general science education course reform is paying the Chemistry Department additional dividends which are discussed in this chapter.

This SENCER formatted curriculum focuses on environmental risk assessment and the basic chemical aspects of environmental remediation. To teach students how our society is attempting reclaim contaminated parcels in the United States, specifically Superfund sites, the faculty member needs to step out of his/her general comfort zone and relies on many partnerships to cover the content. This learning community is a collaborative project including other faculty colleagues, support from the regulatory agencies to supplement "the subject matter content", and city development and non-profit agency personnel to facilitate site access and instruction. The Superfund site redevelopment theme is an excellent choice since environmental regulatory agencies are truly interested in educating the public on these challenging sites and good documentation is typically available with respect to the governmental cleanup activities. Students observe that the chemical science and sociological partnership of the curriculum matches the necessary collaboration of site redevelopment where the planned site reuse is critical to the decision making with respect to the levels of the cleanup and what methodologies are used. The selected Superfund site discussed in this chapter, proved to be quite amenable as an instructional vehicle. In other metropolitan areas, other Superfund sites would also be applicable, especially since our society wishes to reclaim older industrial areas for new safe uses.

SENCER RETUrN LC

The RETUrN learning community involves the studying the redevelopment of a Superfund site. The specific general science course in the learning community, titled Urban Environmental Issues, seeks to teach students important principles with respect to environmental risk assessment and has a specific emphasis on chemical exposure risks. In addition, the basics of reaction chemistry are incorporated so students can realize certain aspects in environmental cleanup documentation. The learning objectives of the Urban Environmental Issues course have changed slightly since the pilot offering when the course was paired with an Urban Studies, sociology course; a combined set of learning objectives are listed in the Table of Learning Objectives Linked to Civic Engagement, which is embedded in the SENCER RETUrN model materials (*3*). The more recent course learning objectives, activities and assignments associated with the objectives, and the methods of assessment are listed in Table 1. This Urban Environmental Issues course uses U.S. EPA Superfund risk documents and CAL-EPA risk documents to provide some instruction on the basics of toxicology and environmental risk assessment. Local site specific Superfund documents give an explicit content link, and students study the public informational documents to learn about specific issues. To provide some historical perspective, the students read and participate in class discussions of Devra Davis' book, When Smoke Ran Like Water. Since Saint Mary's College has a Great Books seminar program, this discussion builds on students' general education skills too. The Chemistry in Context textbook, NAS Alameda Superfund site documents and a few selected research articles provide the chemical subject matter.

The laboratory curriculum reinforced the classroom instruction on environmental risks and exposure. The laboratory experiments have gone through only minor revisions since the initial offering in fall 2003. A key aspect of the lab was and continues to be the two field experiments that highlight measuring contaminants and/or pollutants in the air and soil. Since many spectroscopic techniques have been routinely used to characterize Superfund sites, the students were introduced to the spectroscopic method in three experiments, two of which were field experiments. Both field sampling labs were designed with an additional requirement that students write letters to a specific agency on what was experimentally determined, what the related risks are (if any), and references to methods for improving public safety (if known or necessary). The field experiments have supported instruction on the fundamentals of sampling and methods of quantification. As a final result, our students are better prepared to be perceptive citizens who can participate in citizen advisory groups (CAG – this is a public advisory group that EPA Superfund policy supports on general Superfund sites) or restoration advisory boards (RAB – public board for Superfund sites that are federal facilities) in the future. The civic engagement component of the laboratory was extended beyond the two field sampling labs with one additional lab dedicated to educational outreach to the Alameda Point community youth.

As a final civic engagement assignment for the course, students worked in teams to research a specific aspect or clean up action on the Superfund site. To complete this research work, the student teams prepared presentations or reports, which are shared with a community organization at Alameda Point.

Background on Naval Air Station Alameda (Superfund Site # CA 2170023236)

The Naval Air Station Alameda (NAS Alameda) was an active naval station and aviation depot commissioned in 1940. During the base's history, it was typically the home port for aircraft carriers and their associated air wings. Fulfilling the aviation depot role, the base had an industrial complex to maintain aircraft for both the carriers and planes involved in other duties such as antisubmarine detection. The base was created by filling in tidal areas off the western tip of Alameda Island so the resulting land is unconsolidated fill. The base was in operation as the US Navy transitioned from wooden-decked WW II aircraft carriers with propeller airplanes to steel-decked carriers with jet aircraft. The base had housing for personnel and their families, administration buildings, personnel support facilities, hangars for aircraft disassembly and reassembly, test facilities for engines and weaponry, fuel depots, two runways, a control tower, three piers, a seaplane lagoon, and two landfills. The prime objective of this base was keeping aircraft functional, so unfortunately, the base has many specific sites requiring clean up under the provisions of its Superfund listing. Being a WW II era naval base, radium contaminating materials have been found in the landfills, so students learn about radioactive hazardous materials and safety measures with regard to them. NAS Alameda was included on the BRAC III 1993 closure list and was formally closed in 1997.

NAS Alameda was added to the National Priorities List (NPL, i.e Superfund list) in 1999. Numerous site characterization reports and cleanup activities have occurred since the base closure. U.S. EPA has approved some time critical removal actions (TCRA) so students were able to read clean up documents for specific sites. In particular, a large portion of the radiation waste from the installation restoration (IR) site 1 landfill was removed recently and students were able to read the proposed plan for removal of these wastes. With all the possible chemical exposure issues, students were quickly educated that many hazardous materials still exist in restricted areas, where the class is not allowed. The reality of these risks became more evident to the students as they talked with individuals living on the former base during the course. The numerous specific IR sites at Alameda NAS are highlighted on a map that was created by the U.S. Navy Property Management Office for the Restoration Advisory Board (RAB) as shown in Figure # 1; permission to use this map was provided by the Alameda NAS Restoration Advisory Board Navy co-chair, T. Macchiarella.

To complement the RAB map, students have access to downloadable maps from the City of Alameda's documentation, so they can view the reuse plans for this former base. Since the City of Alameda wishes to see this site integrated into their city, the city development staff routinely give an overview presentation on the redevelopment to the class. Students attend selected city meetings to gain an understanding of the city's challenges and to observe how the citizens are taking an active role in pushing for this redevelopment and responsible clean up of the site. The RETUrN learning community benefits from interactions with many other community organizations and regulatory agencies. Many students have a particular interest in the Alameda Point Collaborative (APC, which is the homeless service provider on the closed military base) since the site hosts many one day service-learning opportunities through the College's office for social action (CILSA, Catholic Institute for LaSallian Social Action). This curriculum successfully demonstrates that science courses can have civic engagement components to complement the College's mission goals and the outreach to APC made this project a very successful endeavor for faculty and students. Regulatory agency personnel also make presentations to the class regularly to give students more up to date information on the clean up activities to support the redevelopment of the site, which now has a new name, Alameda Point.

Urban Environmental Issues Curriculum

The Urban Environmental Issues course was developed to teach central concepts of environmental risk assessment with an emphasis on chemical exposure. Using a Superfund site as the living laboratory, students are also taught basics of chemical reactions, which links directly to site remediation and clean up technologies. The principle learning objectives are listed in Table 1. The experiments were organized to mitigate students' initial fears of succeeding in the lab, then to learn how regulators may characterize a site, and finally to evaluate whether a clean up activity was successful. The characterization aspect was typically fulfilled by learning about spectroscopic methods. To match the site characterization work of regulators, the students screened the soil samples for contaminants applying a high tech method, EPA Method 6200 (*4*), which is an U.S. EPA X-ray Fluorescence (XRF) site screening method. To develop student communication skills, students were required to write letters for the field sampling labs, such as the XRF soil screening lab. In addition, student team research projects were also presented in a public forum.

Students read various documents and in class discussion of the text follows. The class discussion allows students to gain more insight on the potential biases in the documents. This aspect was also voiced in the supporting text authored by Devra Davis. After the pilot LC was run, the Chemistry in Context textbook was used to enhance the delivery of the chemistry content knowledge, replacing two supplemental chapters, Chapters 25 and 26, that were a part of Stanley Manahan's Environmental Chemistry 6th edition text (*5*). Students were required to attend a public meeting and observe different perspectives voiced on specific redevelopment projects. Beyond hearing the general public accepting their responsibilities with respect to the redevelopment of the former Navy base into an integrated portion of their community, students were required to write a reflective summary of the meeting. Students also performed one specific educational outreach project during the term. All these aspects have lead students to have an experience where civic responsibilities are modeled and science content is tied to a societal issue; in this case, remediation of contaminated sites for future productive use.

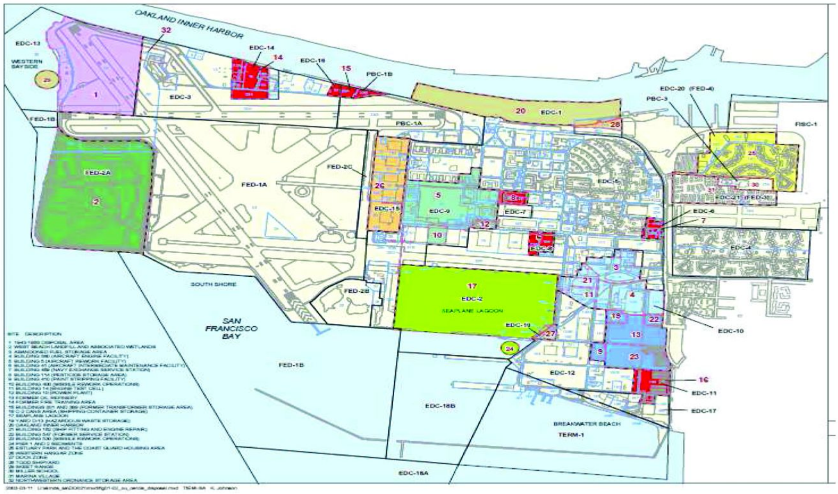

Figure 1. – NAS Alameda Installation Restoration (IR) site map: Specific IR sites including the two landfills near the end of the runways (left side in violet and green), seaplane lagoon near the center (in light green), etc. This map is also available as a pdf at the US Navy Property Management Office website (www.bracpmo.navy.mil/ on the images page of the former NAS Alameda installation website). (see color insert)

Urban Environmental Issues Laboratory

The laboratory curriculum was created in the summer previous to the pilot offering and only minor changes have occurred since that time. The laboratory curriculum was organized with two major focal points: the basics of reaction chemistry and the spectroscopic method. One additional lab was repeated after modification to support the educational outreach to the community. During lab check-in, students were given a chemical reaction balancing worksheet which gave the students some practice and allowed the faculty member to gauge the student's chemical knowledge. The two reaction chemistry labs were a gas generation and thermal change experiments. The gas generation experiment followed materials of Bruce Mattson, Creighton University explicitly which are accessible via the internet (*6*). The experiment was a good qualitative laboratory experience to start the semester. This experiment was also reformatted to use in the educational outreach lab dependent on student interest. The thermal change experiment, was developed following a report in the literature by Charles Marzzacco (*7*). The thermal change lab demonstrated that breaking and making new chemical bonds in a chemical reaction will yield either an exothermic or endothermic reaction. Furthermore, the thermal change lab also gave students an opportunity to observe a reaction catalyst in action. The lab utilized computer-interfaced temperature probes, so the students collected data in a manner nearly identical to the General Chemistry lab. For students, the challenge was the calculations at the end of the experiment. An important context link in this lab, the iron catalyzed decomposition of hydrogen peroxide reaction matched a typical reaction used for *in situ* chemical oxidation (ISCO) which is routinely applied to degrade organic contaminants in the ground water at Alameda NAS.

With the spectroscopic method as a learning objective, three labs were dedicated to this concept. A General Chemistry aspirin quantitative analysis experiment was performed with minor modifications. The two week XRF soil screening experiment utilized the U.S. EPA Method 6200 as a template for the lab. Since the instrument generates X-rays, safety aspects of using this instrumentation to obtain the spectral data were explicitly discussed. Radiation safety procedures with respect to time, distance, and shielding gave students a formal radiation risk assessment in the lab which parallels the chemical risk assessment instruction in the course. Students were provided background on the relative risks of exposure to radiation and an informed consent form has always been used, so each student can make an informed choice on whether to trigger the instrument. Any student may be excused from triggering, however all students are required to process the resulting data. Since the instrument yielded a downloadable Excel file of the elemental soil analysis, the students were typically processing the data very smoothly. The NO_2 monitoring lab also supported the spectroscopic method objective and was conceptually very good (*8*). This lab was adapted from an Environmental Chemistry Lab. The general science students learned about the challenges of field sampling through their two field sampling experiments. The results of the field sampling experiments were communicated with the respective community agencies, which included the Alameda Point Collaborative.

Community Outreach

The Urban Environmental Issues course was designed with numerous community outreach aspects. The students take one field trip to Alameda Point to learn from city development personnel and APC staff. The students host an educational outreach lab for APC's after school program. The lab experiment was typically a repeat of either the gas generation lab or the thermal change lab, which the college students already completed themselves. The outreach explicitly supported the notion of reciprocity with the community, since both the college students and the after school program students gain from sharing a lab experiment and a general discussion on why college is important in one's life. The college students were reminded that college is still an opportunity from these discussions. The XRF soil screening experiment results were shared with the community. Finally, the student team research were completed by generating posters and written reports. The posters were presented to both the College and the community. The written reports graded in the linked sociology course.

Table 1. – Learning Objectives for Urban Environmental Issues Course 2009

Student Learning Objectives	*Teaching/Learning Activities*	*Student Assessment Methods*
1) Evaluate basic factors in environmental risk assessment dependent on medium 2) Explain basics of reaction chemistry	1) Reading, Writing, and Discussion which includes government Superfund documents 2) Observe in Laboratories	Exams for content; Students discuss risks in: 1) XRF soil data analysis. 2) project material incorporated into website. Present pesticide screening data to APC personnel.
Analyze and interpret spectroscopic data and apply method as a quantification tool.	Three labs utilize spectroscopy.	Prepare lab reports and analyze data.
Analyze trends in data	Analysis of field sampling experiments and write letters to agencies	Students prepare lab summaries, tables, and graphs. Students write letters on experimental results.
Quantify elements or compounds and relate it to human health risks.	Soil analysis and air pollutant monitoring coupled to EPA documents	Lab report and written letters to authorities.
Critically Read Documents and evaluate perspectives	Review government documents and scientific research articles.	Constructive participation in discussion of readings.
Synthesize information and recognize potential bias	Listening to different voices	Creating website project materials which show various perspectives.
Communication skills	Critique EPA Videos & web resources; Create the materials for course's website.	Quality of reports to class.
Communication skills with respect science improved.	Writing letters to summarize soil analysis and summaries for website.	Logical construction of informative letter and web materials
Increased sense of civic responsibility	Community experiment; respectfully attending RAB meetings or events.	Student self assessment of civic responsibility.
Formulate opinions on local environmental concerns	Review issues and learn where to find valuable information on issues	Self assessment of students' ability to find appropriate information

2003 Pilot Learning Community (LC) Curriculum

The new Urban Environmental Issues course was linked to an existing upper division Urban Studies course. The curricular objectives were carefully mapped out by the faculty and the educational institution supported this new endeavor well (one course release for each faculty member) while teaching this new learning community. For the civic outreach components to be effectively implemented, the faculty had numerous meetings with both, city development staff and Alameda Point Collaborative personnel prior to teaching the pilot LC. The class size was 10 students and this made the field trips out to the Alameda Point very easy, typically using college vans. The typical transit time to Alameda Point from the College was 45 minutes. The field experiments were performed on site without difficulties in part due to the pre-planning. Additionally, student team research reports were directly coupled to specific environmental issues of Alameda Point (e.g. restoration of the seaplane lagoon, development of recreational sport facility on site, etc.). The student team research was then presented to the College and community in two poster presentation forums. Again, the research was conducted with reciprocity for the community instilled in the students.

The field experiments were very effective in the first trial. The XRF elemental analyzer was a rental instrument and it was only used at the campus after collecting soil samples on site because this instrument contained a radioactive source and it would have necessitated a specific federal permit to use on site. The field site was the planned location of the APC future plant nursery. The class collected surface samples and when the EPA toxicologist reviewed our data, this critical point was identified as an area of improvement. The NO_2 monitoring experiment was the second field experiment and the students made comparisons between the locations in Alameda and the Saint Mary's College campus which almost a rural location in comparison. The NO_2 monitoring experiment was taken directly from a Journal of Chemical Education article (*8*) and reinforced the spectroscopic method, a learning objective of the course.

The students were initially unsure about the community engagement aspects of this learning community. Their group research project required a simple videotaped interview of an official or member affiliated with some aspect of the redevelopment. This requirement challenged the students to b very responsible and respectful. The students had a good deal to learn from the people working on and planning the future of this Superfund site. The final video materials submitted by the teams were sufficient for a grade, but much of the material was onot considered of sufficiently high quality to manufacture a semi-professional DVD on the status of the redevelopment. The process of preparing these videos and accompanying poster did allow the student to become actively engaged in the community aspects of the course.

Learning Community Spring 2006

The Chemistry and Sociology courses were again linked. However, in this iteration both courses were lower division. The Urban Environmental

Issues course was linked to an introductory Sociology course titled Social Problems. Having both courses as lower division was more amenable to the students enrolled. The Urban Environmental Issues course texts were again the Chemistry in Context textbook published by the ACS and the supporting reader titled "When Smoke Ran Like Water" by Devra Davis. The laboratory curriculum was essentially the same as the pilot offering. However, the student team research project work was modified since both courses were lower division. The goal of the LC was to produce a webpage that communicates both the science and sociological research work back to the community. This change was to remove the students" concern about the video aspects in the pilot LC (this was before U Tube, so possibly the video methods could be employed in the future). To facilitate giving another group of citizens a stronger voice on the redevelopment, a focus group involving members of the Alameda NAS Restoration Advisory Board (RAB) was also arranged. Students helped generate questions for this focus group and my skilled sociology colleague, Phylis Martinelli, facilitated the focus group. With permission the excerpts of the focus group were posted as digital audio files, so the opinions and statements of the RAB members are truly being voiced. The class generated good quality materials on their sociology assignments which were also posted on the website which the faculty assembled after completion of the spring semester. The site is still available (http://galileo.stmarys-ca.edu/superfundalameda/). This website was our contribution back to the community in addition to the educational outreach to the Alameda Point Collaborative during the term. This educational outreach experiment involved using the thermal changes lab to support the after school education program at APC after having a half dozen youth tour the Saint Mary's College campus with the LC students serving as tour guides.

One major laboratory challenge occurred during this 2006 learning community. The access to a field site in Alameda Point was a horrible legal issue. However, an alternative site at a residence in Oakland was a perfect remedy. The residence was a 1940's era construction and had peeling paint. The responsible owner, a faculty member, knew that there was lead-based paint on the residence so the soil screening experiment became an investigation of the lead in the soil at locations adjacent to the house in contrast to sampling locations far removed from the house. This alternative site demonstrated that many people do live in homes that still have lead-based paint and that exposure to lead is still a real issue. The background soil samples were approaching the instrumental detection limit and the locations adjacent to the house were a factor of five more than the background spectral results. Furthermore the lead paint chips made in situ soil spectral sampling show the inhomogeneous nature of the distribution of lead so the students gained greater insight on field sampling methods. This experiment also took advantage of information presented by the EPA region 1 lead safe yards program (*9*) which gives a straightforward protocol for selecting sampling locations around residences that are suspected to contain lead paint. The students still used the EPA method 6200 (*4*) to collect the *in situ* spectral data and data was meaningful since a number of the students knew the faculty member who volunteered their residence as our field site. This successful experiment was recently published in the Journal of Chemical Education as a novel environmental experiment (*10*).

The formal civic engagement educational outreach was hosting another group of youth from APC to perform an educational experiment on the Saint Mary's College campus. This allowed students in the APC after school program (middle and high school youth) to tour a college campus and to do a lab experiment with college students as their guides throughout the afternoon. The college students gained considerable insight on the privileges that they currently enjoy. This formal outreach was coupled with another community outreach activity which was the focus group with the Alameda NAS RAB members as noted above. In both activities, students began to recognize that civic responsibilities were in their futures too.

Learning Community Spring 2007

Various circumstances led to some major changes in the learning community during this iteration. Unfortunately my colleague, Phylis Martinelli was away on sabbatical so the Urban Environmental Issues course was in need of a partner to keep the learning community going forward as two linked courses. The Urban Environmental Issues course did not necessarily change in its focus. Since the course was paired with different course in the College's Liberal and Civic Studies (L&CS) program and the student population in the L&CS program are dominantly the pre-service teachers at Saint Mary's College. L&CS course is titled Global and Environmental Responsibilities and for this term the Devra Davis text became a shared text. A large number of students have typically selected this major so the enrollment in the learning community grew to 20 students. This change was not necessarily detrimental however the laboratory experience were somewhat less productive with a 20 students to one instructor ration for the laboratory experiments.

Recognizing in advance that our class size was too large to host the small population of students in the APC after school program without overwhelming them, the two instructors found an alternative that utilized the potential of the 20 college students. The educational outreach occurred at the local middle school that serves Alameda Point and western Alameda Island. The gas generation experiment was a good tie-in to the 8th grade science education standards and the middle school administration and staff appreciated that our class could be split into two groups of ten students to support bringing this lab into all the 8th grade class that met in one day. Since a majority of the college students were pre-service teachers this project was aligned with their educational goals. The reflective discussion on this public outreach was held in my colleague's course. The formal civic engagement event for this term was the educational outreach and the impact was terrific as more than 100 middle school students were able to do a laboratory experiment which would otherwise not be possible.

The field experiments were still organized in a similar manner. An XRF soil survey was hosted on a site that APC wanted to gain more knowledge on with respect to possible contaminants. The NO_2 monitoring experiment was very effective with 20 students quickly placing the diffusion tubes throughout the field site on Alameda Island. The experimental results were reported to the appropriate entities. For the NO_2 experiment, there was more than three years of data on the same field sites. This aspect allowed students to observe weather dependent trends from this historical data, so students realized that sampling in the environment can yield differences due to changes in additional variables.

The students were challenged by the curricular material throughout the two courses. The team research project work involved interviewing a community member and students did not necessarily take this responsibility seriously so the resulting interviews were not as professional as the instructor wanted. The students also expressed concerns about the level of work needed for both courses however the general level of concern for the community was still a positive. Both instructors were still willing to run the two courses again linked, however the following year a smaller student population made the learning community intractable.

Spring 2008 – Urban Environmental Issues Goes Solo

The challenge of running two courses linked as a formal learning community was again present for the academic year 2008/2009. The student population in the Liberal and Civics Studies program needing to fulfill a general physical science requirement was small and my sociology colleague was not schedule to teach a course that could be adapted. Considering the strong partnerships established with the Alameda Point community, the tested laboratory experiments, and the Urban Environmental Issues course was drawing a sufficient small student population, the course was offered alone with the similar educational goals. The missing component was the strong infusion of sociological perspectives. To partially compensate, the students were required to attend public forums on the redevelopment and the faculty provided them with transportation since access to the site was limited.

This year the course had three field experiments. The XRF soil survey and the NO_2 monitoring experiments were again used. Since the APC youth had begun a formal garden to grow edible nutritious food, a determination of important crops nutrients was the selected educational outreach activity. This required that the Saint Mary's College students gain some expertise with some simple educational soil test kits and then provide instruction to APC high school youth. As simple as the experiments were, the portability of the kits allowed this project work to occur at APC and it again reinforced the sociological point that our research in the community requires working in reciprocity.

As noted above, students in 2007 and 2008 were able to observe trends in the average ambient NO_2 gas concentration dependent on additional factors such as the weather. The Webster/Posey Tube site represented a high traffic zone and is within a mile of the Superfund site. Students learned that recording data in the field is possibly subjected to vandalism which reinforced the need for multiple sampling locations at any field site. The NO_2 gas was monitored using five or more locations at the Webster/Posey Tube field with triplicate or quadruplicate diffusion tubes at each location and the results are shown in the Table 2.

Table 2. – Alameda Island Field Site Average Ambient NO_2 Concentrations

Sampling Date	*Average Ambient NO_2 (ppb) and Standard Deviation*	*Weather and Site Conditions*
Spring 2005*	7.4 ± 0.4	Sunny and Dry
Spring 2006	3.3 ± 0.9	Rainy
Spring 2007	7.8 ± 1.8	Sunny and Dry
Spring 2008	8.3 ± 1.6	Sunny and Dry

* A similar General Science course was offered in Spring 2005 and the NO_2 monitoring experiment was a part of that course using the same field site.

Added Dividends

XRF Experimental Work

The LC has had a focus on environmental risk assessment and there are many possible issues to explore. The list of chemical hazards discovered at the Alameda NAS site obviously generated the decision to add the site to the National Priorities List (NPL, which is the Superfund list). With two landfills on the former base and full scale industrial complex, various carcinogens, heavy metals, pesticides, and radioactive materials have been identified at various IR sites. A large portion of the readily accessible housing stock on the Superfund site, including housing in use by APC, is sufficiently old to have lead-based paint, so the issue of lead exposure was readily adaptable. Using the Devra Davis text readings on the incorporation of lead in gasoline and the long struggle to ban it, the students were prepared to study the issue of exposure to lead and were genuinely concerned about it. To give students an opportunity to study this issue, a laboratory experiment was developed. Fortunately, the technological advances for site characterization of Superfund sites have yielded instrumentation such as field portable X-ray Fluorescence (FP-XRF), which readily quantifies lead and many other elements. This type of instrumentation was easy to operate and the sampling can occur on site, so students can gain a better understanding how scientists characterize a site. The XRF yielded elemental data and this fluorescent spectroscopic method can be related to a simple Bohr model of the atom so all general science students can utilize a sophisticated instrument and conceptually understand how it operates.

This instrumentation was initially rented for use in the Urban Environmental Issues lab. Gaining familiarity with rental instruments has allowed the instructor to plan out more field experiments quantifying lead in highway median soils and painted surfaces which were incorporated into the Environmental Chemistry course. During the initial rentals, some novel biology labs were also piloted. As the novel XRF experiments were developed, the faculty received internal support to again rent XRF instruments since the social justice aspects of the new labs were directly aligned with the College's mission. College administration and alumni were generous supporters of this initiative which then strengthen a grant proposal that received external support from the Dreyfus Foundation to purchase a new field portable XRF. Since the arrival of the field portable XRF, a chemistry colleague developed two experiments, a glass analysis and painting forgery investigation, for the Instrumental Analysis course. As a part of the grant funded work, the XRF was integrated into a General Chemistry lab demonstration, too. So the technological innovation piloted in the general science course became a tool for both lower and upper division chemistry course labs. The civic engagement dividend continued to payoff since the same two Chemistry faculty have succeeded in obtaining another grant to incorporate civic engagement into additional labs using other screening methodologies similar to the XRF.

Following information presented at the website (www.clu-in.org) which contains various U.S. EPA supported research materials ranging from vendor reports on new screening methods and innovative hazardous waste remediation studies, the faculty gained insight on newer methods based on fundamental chemical reaction pathways. In particular, the Field Analytical Technologies Encyclopedia (FATE) webpages have proven useful as an instructional tool for both Environmental Chemistry and general science students because a webpage investigative assignment has been created for each course. Plus, this website provided important details on immunochemical detection methods for pesticides, which has lead to a successful proposal to a local private foundation to fund the implementation of screening for pesticides using ELISA kits and applying plate readers to quantify the results, as one critical aspect of the grant. The medicinal and environmental aspects of this second grant proposal met the expectations of the foundation and we were able to claim that our success in integrating the XRF instrumentation demonstrated that we could again be successful with their support. Again a versatile instrument was added to the department's collection and the whole department benefits from the general science education reform.

College Outreach

The learning community was successful due to the numerous partners in the Alameda community. Both the city development staff and the Alameda Point Collaborative (APC) residents and staff have become collaborators in the delivery of this curriculum. The state and federal regulators have always noticed and encouraged the college students when we attend public meetings. The regional EPA office personnel have routinely presented in the classroom salient facts on the site remediation work. The state highway department required permits to place the NO_2 diffusion tubes along the highways and their service has been very prompt especially considering the requests are for no fee permits. As noted, the access to field sampling sites by the Alameda Point Collaborative (APC) has truly benefited the curriculum. The APC staff have appreciated that the College faculty provide the best data possible that students can collect and that using screening methods such as an XRF instruments can give the community additional confirmation data to support site clean ups were complete.

The dividends are that faculty and students are getting positive interactions with environmental regulatory personnel. When the U.S. EPA regional office has an open forum, our faculty are invited to attend. When useful EPA web materials disappear at times through our contacts with the regional office, we have found that these materials can be restored or pdf files can be made available. The positive interactions with city development staff have continued and they seem very appreciative that we continue to bring students out to observe the slow redevelopment of their city's site. The established partnership with APC has not only benefited the Urban Environmental Issues course, but many other Saint Mary's College courses. The benefit to APC was that many projects have been completed in thanks to student service-learning hours spent at APC over the past several years. The outreach to APC was well aligned with the College's mission to assist the underserved so this partnership should continue to grow. The College has made a commitment to include social justice action initiatives as a part of the general education goals so improvements in civic engagement should continue at the College.

Faculty Development

Receiving direction to teach a non-STEM majors general science may not be a preferred assignment at many educational institutions and reforming the general science curriculum may be perceived as a thankless task. The connection to the SENCER project made this task an enjoyable exploration. The general aspect of working with another faculty colleague in a learning community was an intellectually stimulating environment. Colleagues demonstrated different special skills in a learning community set of courses to the benefit of both the students and their respective colleagues. Sharing the tasks of responsibly reaching out and learning with the community of Alameda Point has been and continues to a delight with respect to this curriculum. On a more mundane level, the involved faculty have developed new skills including the preparation of websites which is not necessarily so grand, but it is now additional tool to use in chemistry courses. The faculty have investigated other screening methodologies and this supports chemistry curriculum reforms.

The integration of the field screening instrumentation has lead to a whole new area of research for the chemistry faculty involved in this project work. As noted above, an XRF soil sampling laboratory yielded sufficient quality data, so that the faculty member wrote a Journal of Chemical Education article and has presented at numerous American Chemical Society and multi-disciplinary conferences. The successful incorporation of civic engagement aspects in the general science lab has lead to Environmental Chemistry lab curriculum opportunities too. After legal hassles kept the learning community from doing an XRF lab at Alameda Point in the spring, an interesting site became available for the Environmental Chemistry lab in fall 2006. The site of a radio tower which was painted with lead-based paint was being reevaluated for lead in the soil since the final cleanup report noted sampling did not address the prevailing wind that could yield paint chips more in one particular direction. The site was not necessarily considered unclean, but the APC community appreciated having an independent test of the surface soil outside the area that was remediated. It gave the Environmental Chemistry course a defined sampling assignment. The documentation on the removal action and the community's interest made the experiment more important to the students. The class's results demonstrated that no soil lead was observed above the limit prescribed in the cleanup protocol, so the community was given some positive news with respect to this site. The Environmental Chemistry students more clearly recognized their responsibilities as they moved forward to join the future workforce. Again the Environmental Chemistry lab benefitted from the faculty member's involvement in the general science course and the same field portable XRF was used by students in a both lower division and upper division courses.

General Conclusion

This curriculum has explicitly linked the science content to a critical regional issue which is the redevelopment of Superfund site. The partnership of faculty from the physical and social sciences yielded a dynamic curriculum serving the College's outreach mission. The study of this changing community was and continues to be done with reciprocity to the benefit of both the College and our community partners. The general science laboratory innovations developed in this curriculum have provided benefits to the Chemistry Department's major curriculum through instruction on the utility and limitations of screening methods such as XRF. Incorporating civic engagement such as in this RETUrN learning community and the specific Urban Environmental Issues course, has allowed faculty to continue to be rejuvenated each time the course is taught and student clearly observe the relevance of the science and its contribution to civic issues.

Acknowledgments

This curriculum was developed in partnership with many colleagues. The tremendous efforts of my colleague, Phylis Martinelli who worked on the pilot 2003 Learning Community, 2006 Learning Community, and the SENCER model course materials are acknowledged. This learning community blossomed due the partnership of both instructors in both designing and implementing the curriculum. The time and resources expended by the City of Alameda Development Department are truly appreciated, especially Debbie Potter's contributions. The Alameda Point Collaborative executive directors, Jack Shepherd and Douglas Biggs, and other APC staff have also made this learning community a success. Their patience with us as partners is acknowledged. The EPA region 9 personnel were instrumental in clarifying clean up actions and basics of toxicology which enriched this curriculum immensely. The efforts of Thomas Macchiarella, NAS Alameda Restoration Advisory Board Navy co-chair providing materials on clean up activities are acknowledged. T. The institutional support of the Provost's Office allowed the faculty to more readily generate solutions to logistical problems and to pursue the many successful avenues of the work. The many students who trusted the faculty to create an integrated learning experience and stepped out of their comfort zones of a traditional curriculum, are also acknowledged.

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Chapter 9

Engaging Students in Science Communication

An Experiential Learning Model

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Preparing science students to communicate more effectively with broader audiences throughout their careers is a critical need that has drawn national attention, particularly in the field of chemistry. Results of a recent Discovery Corps Senior Fellowship from the NSF Chemistry Division have emphasized the importance of public communication of chemistry. This chapter describes an experiential learning program at the University of Washington that engages science students in real reporting and writing experiences. Graduates have successfully applied the experience working at national publications and in Congressional fellowships.

Given that the United Nations has formally declared 2011 as the International Year of Chemistry (*1*), it is perhaps an auspicious time to focus on public understanding of chemistry and strategies to enhance the preparation of chemistry students and professionals to communicate with the public about their science. The upcoming celebration of all things chemistry comes at a time when national and international attention has been focused on the need to prepare scientists to communicate more effectively with broader audiences (*2–4*).

In an editorial on “Outreach Training Needed,” executive publisher of *Science* Alan Leshner urged university science departments to “design specific programs to train graduate students and postdoctoral fellows in public communication” (*2*). Increasingly, scientists are expected to demonstrate that their research efforts will have broader impacts and they are communicating the results of taxpayer-funded research to general audiences.

Evidence of the increasing need to enhance the ability of scientists to communicate with general audiences was the bill introduced in Congress in March of 2007 that would have provided support to NSF for communications training for graduate students in order to improve the ability of scientists to interact with policymakers (*5*). Further evidence was the recent experiment by the journal *Science* to ask authors to provide more accessible summaries for research papers (*6*).

Trends in the workforce also are intensifying the need for science communication training. Graduates of the higher education system will need to communicate throughout their lives in a variety of settings and to many different audiences. The workplace is becoming global and multidisciplinary; individuals may be called upon to work in teams (*7*) and to communicate across disciplines and cultures.

Concerning the National Research Council report, *Bridges to Independence* (*8*). Benderly notes, "The traditional 'linear progression' from 'graduate school to postdoctoral positions to assistant professorships, then obtaining funding and tenure' now works for only a small minority of young scientists" (*9*). Benderly continues:

> "Instead of this simple progression, young scientists confront 'a complex network of current career pathways' to a variety of occupations using scientific training, many of them outside academe. . . . The great majority of postdocs seeking stable career employment must therefore take what the academic world has long regarded as 'alternative' jobs with unfamiliar professional cultures and skill requirements that scientists generally do not encounter in graduate school or a mentor's lab (*9*)."

These trends are occurring in many fields, and it has been widely recommended that students and postdocs receive a broader preparation for diverse careers (*9–11*).

The preparation of more effective informal science educators, scientist-communicators, and "civic scientists" (*12*) will be critical in order to advance science literacy and enhance public understanding. Yet, as Leshner notes, "Engaging the public effectively is an acquired skill, and preparation for outreach strategies has seldom been part of scientific training programs" (*2*). One initiative, the Aldo Leopold Leadership Program (*13*), is aimed at mid-career scientists in the environmental arena, but it reaches relatively few professionals (some 100 between 1998 and 2006, according to (*14*) and does not reach students while still in school. The American Association for the Advancement of Science has offered for over thirty years its mass media summer fellowship program that places a few dozen science graduate students per year as interns in media outlets (*15*).

The field of chemistry faces perhaps one of the greatest challenges of any scientific discipline in terms of public communication. I don't think it's going very far out on a limb to say the state of public understanding of chemistry in this country is "in crisis."

Bruce E. Bursten, Past President of the ACS, talked about the need to remove "the cloak of invisibility that often conceals the good performance of chemists and chemistry from public appreciation (*16*)." As ACS President-Elect, Thomas H. Lane in collaboration with Wayne E. Jones, Jr., Chair of the ACS Committee on Local Section Activities, issued a call to arms to ACS members asking for their help to "make a dent in the misperceptions surrounding chemistry, chemists, and chemicals" (*17*).

To achieve that goal will require not only that chemistry professionals become involved in public communication, but also that we begin to provide preparation to chemistry students at the undergraduate and graduate levels in strategies of communicating with broader audiences. There is a long way to go. As evidence, I would cite the extremely low participation to date by chemistry students in our courses at the University of Washington on writing about science for general audiences. Along with engineering, chemistry has been one of the lowest subscribers. The largest demographic, by far, has been biology.

But how to approach the design and delivery of communications training for university science students on a national scale--and chemistry students in particular--remains a challenging question.

One of the central issues is the question of national capacity: the number of chemistry students nationally who have access to courses specifically aimed at writing for broader audiences is hard to estimate, but likely quite low. One approach to such an estimate is to use the national inventory of science journalism programs developed by Sharon Dunwoody (*18*), which lists some 49 entries nationwide consisting of individual courses as well as programs. But even if universities have such programs, the extent to which chemistry undergraduate and graduate students participate in them likely is low.

Unfortunatley, as Lewenstein and colleagues note, "most communication training for scientists begins after a prominent scientific discovery, and the training often occurs in a trial-by-fire style" (*19*).

At the University of Washington, we have been working over the last ten years to develop learning strategies to prepare university science students to more effectively communicate with broader audiences. Our goal has been to find new approaches for equipping science students with the genres of writing that they will use throughout their lives in both informal and formal settings as they interact with diverse audiences about science content. It is an approach we call "Writing for LIFE (Learning in Informal and Formal Environments)." These are genres that chemistry professionals would use to communicate about their science with policymakers, journalists, community groups, industry leaders, funding agencies, K-12 audiences, and museum audiences, among many others.

Based on a decade of teaching communication to science students, we have identified some of the greatest barriers to enhancing science communication and possible ways to overcome them. The most frequent problems we encounter in the writings of science students, especially graduate students, have to do with issues of audience: use of jargon, parroting technical explanations, including too much technical detail, inadequate explanations, and inappropriate order of information. Informal "show of hands" surveys have revealed that a majority of science graduate students have essentially no, or very little, contact with non-scientists on a daily basis, and therefore little opportunity to develop mental models of what is appropriate for general readers.

Outcomes of the program have revealed that our experiential learning approach to science writing enhances communication skills and helps to supply the pipeline of technical communicators needed to translate science for broader audiences. Indeed, all of our award-winning writers have been science graduate students.

But there have been additional benefits not foreseen. Engaging students in real-world reporting assignments has provided other kinds of educational and professional development effects.

First of all, the experiences complement conventional learning in science. It allows students to see how the scientific process is carried out in practice and to situate science learning in societal context. Students become better self-starters, and they engage with role models, develop poise, gain knowledge of professional practice and societal issues, and become aware of internships and jobs (Table I). Research to systematically measure these effects continues in our laboratory.

The sections below provide information on the historical development, content, and outcomes of our experiential learning curriculum in science communication. Finally, I offer a few thoughts on a roadmap for a chemistry communication initiative.

Table I. Potential Benefits for Professional Development of the Experiential Approach to Science Communication

Real-world reporting assignments may help chemistry students to:
• Avoid compartmentalization of knowledge
• "Think on their feet"
• Situate science in societal context
• Learn the real process of science
• Evaluate evidence
• Support life-long learning
• Develop analytical thinking skills
• Prepare for outreach, public service
• Develop poise and professional skills
• Gain contact with role models
• Develop awareness of career options
• Gain advantages in job hunting

Figure 1. Northwest Science & Technology magazine serves as an educational platform and research laboratory in science and technology communication. Sample covers of the print and online issues (www.nwst.org).

Table II. Enrollment in UW Science Writing Courses: 1999-2006

Total "enrollments"	350
	Percent of Total
Graduate students	45%
Undergraduates	46%
Nonmatriculated, postdocs, or employees	9%
Arts & Sciences (A/S), all levels	48%
Science Departments, all colleges	56%
Bio-related Science, all campus	22%
Engineering (non-Tech. Comm)	3%
Science & Engineering	~60%
Non-science (Comm, English, History of.Ideas, etc)	40%

Table III. UW Science Writing Courses Span the Spectrum of Genres for General Audiences

	Fall— *Hard News*	*Winter—* *Features*	*Spring—* *Creative Nonfiction*
Typical Genres	Press Release, News Brief, News Article	News Article News Feature	- Narrative - Profile - Review - Essay
Topic Criteria	Newsworthiness Strong News Peg Strict Timeliness	Relaxed Requirement for Timeliness & News Peg	Timeless Themes in TimelyEvents
Format	Inverted Pyramid	Modified Pyramid —Multiple Themes	Various Structures
Relation of Writer to Subject	Writer as Transparent Observer	Writer as Analyst, Synthesizer	Fusion of Observer & Observed
Style	Efficiency, clarity	Analytical	Descriptive, Figurative

Background on the UW Science Writing Program

I have developed a curriculum in science communication that draws from my experience as a reporter for *Chemical & Engineering News* and my research experience both in chemistry and in communication. The set of three courses is open to a mix of graduate and upper division undergraduate students from all campus units--nearly 60 percent on average come from science as shown in Table II . The mix of disciplines provides a rich and diverse set of viewpoints that are tremendously valuable in the review of student articles. The mix of levels provides a learning continuum with more advanced students helping to mentor the less advanced.

A unique feature is the connection to a regional magazine, *Northwest Science & Technology (NWS&T)*, founded as a training ground for writers and as a laboratory for my research in science communication (Figure 1). The courses have simultaneously addressed the needs of students interested in careers in scientific research; reporting, freelancing; K-12 outreach; law, business, policy careers; and museums, video, and filmmaking, among others.

The establishment of the UW science writing program responded to several factors at play in the late 1990s (*21*). Among them were the issuance of the Boyer report and of the new ABET Engineering 2000 accreditation criteria. The report of the Boyer Commission on Educating Undergraduates in the Research University, published in April of 1998, spurred research universities to draw upon their strengths as research-based communities to make learning based on discovery rather than simply on the traditional “sage on a stage” approach. The report urged research universities to remove barriers to interdisciplinary education, link communication skills and course work, and develop capstone courses.

In the same time frame, colleges of engineering across the country were working to meet the Engineering Criteria 2000 of the Accreditation Board for Engineering and Technology (ABET). Programs now needed to demonstrate that their students gained proficiency in communication skills, an understanding of the global and societal context for technical developments; and a knowledge of contemporary issues.

In this light, a technical nonfiction writing curriculum linked to the production of a regional magazine was seen as an approach that could address the goals of the Boyer report and ABET criteria and at the same time provide a vehicle for public outreach to enhance public understanding of the role and contributions of the research university in society.

Our approach has integrated theory and practice. We use readings from the communication literature in concert with case studies from the print and broadcast media to highlight issues in media coverage of science. Students engage in workshop discussions and interact with practicing writers, public information officers, and publishers. Guest speakers have included Carol Yoon (*New York Times*); Bill Dietrich (*Seattle Times*, Pulitzer-Prize winner); Virginia Morell (*Science, National Geographic, and Discover*); Heather Pringle (*Discover*); Doug Gantenbein (*The Economist*); James Kling (*Science, Nature Biotechnology, The Scientist*); Sandi Doughton (*Seattle Times*); Robert Service (*Science*); Alan Boyle (MSNBC.com), among others. Writing assignments span the genres that readers encounter in popular media, progressing from relatively straightforward hard news reporting assignments to other nonfiction forms (see Table III. Reporting assignments are assigned as follows. I develop a list of potential story topics based upon press releases, research articles, media reports, and other materials collected over the past quarter. Students choose among these, and where there are overlapping choices, they may be assigned their second or third choice of topic. This procedure allows most students to receive a topic that closely matches their areas of interest.

Class sessions cover the basic newsgathering and interviewing skills students need to begin researching their stories. For most of these students, it is the first time they have had to develop an interview guide, contact sources in the community, manage an interview process, and reconcile sometimes conflicting claims among sources.

Students' articles may be considered for publication in *NWS&T*, thereby helping students to build a writing portfolio. At the same time, the UW and regional institutions gain an outreach vehicle, and in the academic setting, we gain a laboratory for testing innovations (see for example reference (*20*)). Examples of student writing may be viewed in online issues of *NWS&T* at www.nwst.org.

In these courses, students have the opportunity to keep a writing journal as a place to reflect upon their real-world reporting assignments. Some of the exercises help students reflect upon their interactions with sources as role models and to think about the process of doing science in practice. Other exercises are meant to cultivate mental models of audiences, what general readers know and don't know, and how media outlets gear messages for audiences. Some sample journal projects are listed in Table IV.

For chemistry students—or for other students assigned to report about chemistry-related stories—these journal exercises provide an opportunity to reflect upon interactions with chemistry professionals, as well as a chance to think about their interactions with non-scientists about chemistry content and about how the media treat chemistry-related content in the news.

Outcomes of the Experiential Learning Approach to Science Communication

The effectiveness of our experiential learning approach has been demonstrated in several ways. First of all, students have earned national placements and/or freelancing assignments in media and research organizations. Several students have applied their science writing experience in Congressional fellowships. Finally, their work has been honored with ten national and international awards for *NWS&T*, including three Best of Show awards from the Society for Technical Communication.

Table IV. Sample Exercises for the Student Writing Journal

1) Make a section of your writing journal to reflect upon your interactions with sources. Select an aspect of these personalities you would like to focus on using your journal: for example, as a career study, note what you learned about the jobs and lives of these scientists, how they think, how they approach their work, and what skills they use. Another possibility is to use it as a tool to improve your interviewing skills by planning strategies for contacting and interviewing sources and/or by using your journal for post-interview analysis and how you could have improved the management of the session.
2) Make a section of your journal as a place to plan and reflect upon interactions about science content with non-scientists (next-door neighbors, fellow bus riders, coworkers) and talk with them about your specialty in science or about current events that involve technical content. Reflect upon these experiences in your journal and analyze what you have learned about general audiences.
3) Make a section of your journal to study and reflect about the way media outlets treat science. What terms to they define and how? What terms do they assume readers know? How are definitions and explanations crafted? What metaphors and similes do they use and how effective are these devices? How long are the definitions and explanations and how are they incorporated into the news item or article? Reflect upon these examples and analyze what you have learned about audiences.

Table V. Characteristics of Novice and Advanced Science Writers*

Novices	*Advanced Writers*
Absolute knowers— Every question has one correct answer and the professor has it	*Contextual knowers—* Responsible for constructing knowledge, evaluating multiple sources & available evidence in face of uncertainty & ambiguity
Have trouble identifying sources; Procrastinate	Self-starters
Don't look to see what else has been written	Thorough researchers
Left to their own devices, they typically interview only one source	Resourceful in identifying sources and judging how many voices to include
Limited ability to judge newsworthiness	Well-developed sense of newsworthy
Neglect societal context	Give societal context for stories
Confound matters of fact and opinion and fail to correctly attribute information	Separate facts from opinions and correctly attribute information
Fail to scrutinize data or statistics	Thoroughly check facts & claims
Often fail to translate jargon	Use accessible language; good understanding of audience
"Parrot" back source information	Can separate author's voice from sources'
Often report only one side of a story	Adept at handling multiple viewpoints, even when sources disagree
Flustered when sources disagree	Poised and savvy; can manage interview process well

* Science writing experiences help students advance in level of intellectual development, moving from the left column to the right.

At the outset, I did not foresee the extent to which this approach would enhance the overall level of intellectual development and self-directed learning readiness of students. My goal at the time was to help raise the bar on quality, accuracy, depth, and balance of media reporting about science and technology. But along the way, I began to realize the significant potential of this curriculum to foster science learning in a way that was complementary to the traditional science curriculum.

Education researchers model the stages of intellectual development as progressing from "absolute knowers" who think every question has one answer and the professor has it, to "contextual knowers" who are able to construct knowledge independently in the face of uncertainty and ambiguity (*22*, *23*). I have found there is a parallel between the stages of this model and the stages that news writing students go through as they learn to report real-world science stories (see Table IV).

Table VI. Results of Supplementary Student Evaluation of "Science & Technology News and Feature Writing" Course, Winter Quarter 2008*

N = 13	*Excel-lent*	*V. Good*	*Good*	*Fair*	*Poor*	*V. Poor*	*Ave*
Please rate this course as a means to:	**1**	**2**	**3**	**4**	**5**	**6**	
Improve writing skills	4 (31%)	7 (54%)	1 (8%)				**1.8**
Improve ability to interact with others in a professional setting	4 (31%)	7 (54%)		1 (8%)			**1.8**
Become a "self-starter" in knowing how to tackle a project	4 (31%)	5 (38%)	2 (15%)	1 (8%)			**2.0**
Understand contemporary issues and societal context	5 (38%)	3 (23%)	4 (31%)	1 (8%)			**2.1**
Improve organizational skills	3 (23%)	3 (23%)	5 (38%)	1 (8%)			**2.3**
Improve project management skills	2 (15%)	6 (46%)	3 (23%)	1 (8%)			**2.3**
Improve time management	2 (15%)	5 (38%)	4 (31%)	1 (8%)			**2.3**
Enhance listening skills	2 (15%)	4 (31%)	4 (31%)	2(15%)			**2.5**

* Table shows number of respondents (total n=13) rating aspects of the course, on a scale of excellent (1) to very poor (6).

Novices have trouble identifying sources to interview; left to their own devices, they typically interview only one source--the lead author of the study. Novices have limited ability to judge what is newsworthy. They rarely look to see what else has been written on the subject; and they "parrot" back the information furnished by the source, without questioning it. They become flustered when sources disagree; they neglect to provide societal context for the particular development being reported.

Advanced news writing students, on the other hand, exemplify the contextual knowers described in the models (Table V).

Over the last 10 years, I have observed the power of news writing in the context of a real-world publication to effect in students a progression toward the contextual knower and advanced self-directed learner. Nearly all students see to make significant gains in this regard, even in the period of the 10-week quarter. Preliminary results (Table VI) show the self-reported effects of the winter quarter 2008 course on aspects of student preparation and abilities. Enrolled were 9 students from bio-related departments, 4 from ocean and fishery sciences, 1 from education, 1 from technical communication, 1 from Earth and space sciences, and 1 from English. No students from chemistry or chemical engineering self-selected to enroll in this class despite the fact that the course was advertised to all departments in the same way.

Student evaluations showed that the science writing course provided an effective means to improve writing skills, improve ability to interact with professionals, become a self-starter, and understand contemporary issues and societal context for developments, with 93%, 85%, 85%, and 93% of respondents rating those aspects, respectively, in the range of excellent to good.

We hear much about the need to foster life-long learning skills and the importance of producing university graduates who possess these skills. Shuman and colleagues have reviewed a number of approaches to teaching professional skills in the context of the engineering disciplines (*24*). The attributes of life-long learning they outline are indeed some of the very skills that make a good news reporter: reading, writing, listening, and speaking; an awareness of what needs to be learned; ability to generate and follow a learning plan; to identify, retrieve, and organize information; to understand and remember new information; to demonstrate critical thinking skills; and to reflect on one's own understanding. Results of our program so far have shown that a curriculum with elements as I have described can foster the development of these traits.

Toward C^3 -- A Chemistry Communication Curriculum

Lane and Jones have asked the chemistry community to commit to "helping put a human face on chemistry" by building new relationships within their communities and across the globe (*17*). They have suggested activities that local sections may want to pursue to enhance public understanding of chemistry.

Within the academic environment, a similar call to arms is needed to mobilize the development and delivery of educational programs to prepare students in the pipeline to become chemistry communicators. It's time to think beyond the traditional "writing in the curriculum" and "writing to learn" approaches that are confined to lab reports and term papers.

What we need is "Writing for LIFE," that is, "Writing in support of Learning in Informal and Formal Environments." Students need to become agile writers, able to gear their writing for a variety of settings and audiences. They need to learn to communicate across disciplines and cultures. There is much to be learned from the science communication research community that can enhance this process, and I would urge chemists to reach out and forge new partnerships in order to be successful in fulfilling Lane's call to action.

In the near term, an experiential learning curriculum in science communication such as the one we have developed at the University of

Washington could be adapted in a Web-based format to expand access to students at other institutions. As a demonstration of the feasibility of such an approach, we recently adapted our curriculum into a modular format for engineering students with funding from the Center for the Advancement of Scholarship on Engineering Education of the National Academy of Engineering.

More recently, we have received funding from the National Science Foundation for a pilot project to investigate new strategies to enhance the preparation of chemistry professionals to communicate with broader audiences.

The overall goal is to cultivate a cadre of chemistry communication leaders who can 1) Help bring about a cultural change in the field of chemistry to value and reward public communication; 2) Serve as champions and ambassadors for chemistry communication efforts; 3) Bring a modular chemistry communication curriculum/resource guide back to their home institutions for use in follow-on activities; and 4) Mentor colleagues and others now in the pipeline at the graduate and undergraduate levels to be tomorrow's chemistry communicators.

We are developing an intensive, hands-on session for a diverse group of chemistry postdoctoral researchers. Participants will receive a resource/guide to use during the following year as they mentor others in their home departments on chemistry communication efforts. This project will generate new knowledge about strategies to enhance the preparation of informal science educators with particular attention to the following central questions:

- To what extent does this course improve chemists' ability to communicate their own research to broader audiences?
- How does the role-playing experience of being a journalist for a few days affect the preparation of chemists to serve as sources for journalists?
- How does this preparation affect, if at all, chemists understanding of and attitudes toward the process of public communication of chemistry?
- How does the course affect participants' ideas, attitudes, plans, and actions with respect to undertaking communication efforts in their home departments?

These questions will be addressed by means of pre- and post-course writing assignments, pre- and post-questionnaires, and follow-up surveys and email and phone interaction with participants.

It is hoped that this project will contribute to the development of educational infrastructure needed to mentor early-career scientists and to prepare them to integrate research and outreach activities in order to communicate in a broader context.

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Chapter 10

Engaging Assessment: Using the SENCER-SALG to Improve Teaching and Learning

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Standard student course evalutions (SCEs) disengage faculty from teaching and its assessment because (1) SCEs cannot help faculty assess their teaching or improve student learning, (2) they cannot be adapted to specific course or departmental learning objectives, (3) they inhibit innovation in teaching and assessment of teaching, and (4) they encourage abuse of the data they provide. The Student Assessement of their Learning Gains (SALG) instrument was designed specifically to overcome these deficiencies. Over a decade of research shows that the SALG is a valid, reliable instrument that offers faculty useful, detailed information about how particular aspects of their courses affect student learning. It provides a compelling alternative to traditional SCEs, one that has the capacity to make course assessment rational, effective and valuable to faculty. It thereby opens a path to re-engage faculty with teaching and with assessment of teaching and learning.

The Context: Faculty Anger about Assessment

The incoming president of the faculty senate at a western liberal arts school surveyed his faculty in fall 2008, asking them what new issues they were most concerned about. "Too much assessment" topped the list. A follow-up survey found that faculty are specifically angry about the increasing amount of assessment they are being asked to do. (Neither of these two surveys nor the one that followed distinguished among different types of assessment. Assessment of student learning is quite different from assessment of faculty performance, which is in turn different from assessment of courses and curricula, yet the three surveys in question lumped all types of assessment together. As we shall see, the conflation of the first two types of assessment contributes significantly to faculty anger.) These results probably did not surprise anyone: an undercurrent of resentment about assessment has been simmering on campus for a few years, as it has at many campuses around the country.

What did surprise the president—himself no friend of assessment—was the intensity of faculty anger. Even he was taken aback by the "vehemence expressed by people normally considered level-headed, including several current and ex-chairs and members of Deans' offices." Comment after comment complained that assessment takes too much time and is not useful. Many dripped with sarcasm. Others were outright derisive. As a whole, the response to the survey displayed a remarkably passionate hostility to assessment. However, the response rate to this survey was quite low—only 40 out of 535 faculty completed it, so it was possible that the respondents self-selected based on their animosity to assessment.

To test this hypothesis (and ignoring the irony of his tactics), the president conducted yet a third survey. A report detailing the results of the second survey was circulated and faculty were asked to vote on whether or not they agreed with the spirit of the report. The result was a landslide: 180 people (87%) agreed and only 27 people (13%) disagreed.

These findings are more typical than atypical. Across the country, assessment has become a critically important issue for faculty, faculty are remarkably upset about how assessment is being handled, and that anger is widespread. Consider, for example, how many people won't even speak the word *assessment* any more, emphasizing their disdain and repudiation by referring to it only as *the a-word*.

The most common complaints about assessment center on how much time it takes and how little value accrues to faculty in return. In one sense, it is impossible to overstate the seriousness of the complaint about how much time it takes: all faculty I know are chronically overworked and overbooked. Therefore any new demand on their time requires them to cut or reduce some other activity they value. Obviously, and understandably, they resent it. But the increased amount of time that faculty are required to spend on assessment by itself does not explain the vehemence of their opposition. Surely it is irritating, but what really gets them going—if the comments made in the second survey are any guide—is the fact that the increase in time they are required to spend on assessment does not increase the value they get out of the process. Indeed, the most passionate diatribes against assessment almost always focus on the fact that it does not benefit faculty.

Here is the crux of the problem: the primary purpose of assessment, and especially of recent increases in assessment activities, is to improve education (and to provide evidence of that improvement). One of the ways it aims to help faculty become more efficient, more effective teachers is by engaging them actively in rethinking the relationships between their purposes (missions, goals and objectives) and their pedagogical practices (methods). Another aim is to engage faculty in research, in systematic investigation of teaching practices and accumulation of evidence about which pedagogies are most effective (for which kinds of students and under what kinds of circumstances) and why. Both are reasonable, even laudable, goals: greater engagement with teaching, clearer understanding of the relationships between purposes and practices, and better research on teaching should all be of value to faculty. Yet instead of facilitating increase faculty engagement with their teaching, the recent push for increased assessment has had the opposite effect. Why?

Student Course Evaluations

The depth and breadth of faculty anger suggest that no single cause can account for the present circumstance. However, it seems likely that much of faculty's dissatisfaction with assessment can be traced to their formative experiences with it. Most faculty's first experiences of assessment come in the form of student course evaluations (SCEs). Five years ago, assessment *meant* student course evaluations for most faculty. Even today, SCEs remain the most common way that faculty participate in assessment: they are required of every faculty member, in every course, every term. SCEs are also the primary basis of rank, tenure and promotion decisions. According to Peter Selden and Wilbert McKeachie, in 2005 SCEs were the primary basis for rank, tenure and promotion decisions at over 80% of American institutions of higher education. At over half, they are the *only* means of faculty evaluation (*1*). Because faculty experience of assessment is so closely tied to SCEs, and because SCEs so directly shape faculty careers, it seems probable that faculty attitudes about assessment are largely formed by their experiences with student course evaluations.

Student course evaluations are surprisingly uniform in American higher education. According to Selden and McKeachie (*1*), well over 70% of American institutions of higher education (IHEs) use standardized forms that share a large number of characteristics. These forms usually consist of between 11 and 17 items. Each item asks students to rate their agreement with a statement about the instructor or the course. Typical statements include: "The instructor presents class material clearly," "The course is well-organized," "The instructor appears well prepared for class," and "The instructor encourages students to ask questions and/or express opinions." Students respond to the statements using a Likert scale that ranges from Strongly Disagree to Strongly Agree or from Low to High. Most scales have five choice-points and allow a neutral answer; but a few use four or six choice-points to force the respondent to make a positive or negative judgment. At most IHEs, all instructors are required to survey students using the standard form at the end of each term. In some cases different colleges may use slightly different versions of the standard form, but at most IHEs all students get the same form in every class, regardless of college. Survey results are usually reported by item and include number of responses, distribution of scores, mean score, and standard deviation.

This method of evaluating teaching contributes to faculty anger and disengagement from assessment in a number of ways. One critical failure is that SCEs do not measure what they purport to measure (or what we want them to measure). Student course evaluations purport to evaluate courses, yet the questions focus not on courses, but on teachers and teaching. The goal of teaching is to produce learning, so assessment of teaching should measure the extent to which it facilitates *student learning*. Yet the vast majority of SCEs focus heavily on student perceptions of *faculty behaviors*: how well prepared they were, how knowledgeable they are, etc. Even the few statements that appear to be about the course (e.g., the course is well organized) are mostly determined by faculty behavior. Some of these faculty behaviors are moderately correlated with student learning (e.g., presents class material clearly), but the correlation is not perfect, so at best these questions probe a probability of student learning, not actual student learning (*2*, *3*). Even worse, some of the items that appear on most SCEs are *not* strongly correlated with student learning (being organized and appearing to enjoy teaching, for example). Because the overall correlation between teaching behaviors and student learning is not that strong, assessment of teaching behaviors does not provide useful insights that lead to better teaching. This is reflected in the fact that although student course evaluation is one of the most heavily researched areas in educational assessment (*4*), there is a dearth of studies on how SCEs are used to improve course design and/or student learning. Indeed, it is unlikely that assessing teacher behaviors produces much useful information at all: most faculty members are already aware of how organized, knowledgeable, and prepared they are. Informing them of students' opinions about those behaviors adds little that will help them assess the effectiveness of their teaching. Centra (*5*) argued that four factors determine whether any form of student feedback actually prompts improvements in teaching: (1) the feedback must include *new information*, (2) instructors must *value* the source of the assessment, (3) the feedback must include *specific information* that will enable change, and (4) instructors must be *motivated* to make changes. Typically, SCEs fail to meet any of these conditions.

Since SCEs do not measure what they are supposed to measure, and do not provide meaningful feedback about teaching or learning, faculty soon realize that they serve purposes other than evaluation of teaching and learning. Indeed, as Seldin and McKeachie point out, the primary use of SCEs is faculty performance evaluation: so an instrument that claims to evaluate courses and should be evaluating learning is actually being used to assess faculty performance (of which teaching is one part). This uncritical conflation of three quite different types of assessment (course, learning and faculty performance/teaching) that serve very different purposes greatly reduces the credibility of assessment as a whole and strongly disengages faculty, not only from assessment of teaching, but also from valuing teaching. (This anger builds on the traditional academic devaluation of teaching in comparison with research. Assessment is linked with teaching, not research.) And the misrepresentation of the purposes of SCEs, coupled with their vital importance to rank, tenure and promotion decisions, does much to fuel faculty anger.

This disengagement is amplified by the fact that most SCEs are standardized, inflexible and applied universally within a school. Because SCEs are designed to be used across a variety of disciplines, the picture SCEs paint of what happens in a given classroom is rendered in extremely broad strokes. SCEs can only measure the lowest common denominators—things like organization, preparedness, etc. They cannot begin to measure how well students are meeting the specific learning goals of a given course, program or department, so they cannot provide faculty with feedback relevant to their particular (or departmentally mandated) purposes. For the same reason, SCEs can never help faculty align their methods of evaluation with their pedagogical methods and goals. That faculty are not allowed to change SCEs in most cases—are prevented from adapting the instrument to their needs—further dissuades faculty from taking SCEs seriously or from taking an active interest in their teaching and its assessment. That SCEs are mandatory even though they violate the first principle of assessment—that evaluation is always in terms of progress toward stated goals—communicates to faculty that the missions, goals and objectives developed so carefully through program review are not taken seriously by those who require these forms of assessment. This gap between the ostensible purposes of assessment and the capabilities of SCEs encourages cynicism and further disengages faculty from their teaching and its assessment.

SCEs also work against diversity and innovation of teaching methods. SCEs embed a set of assumptions about pedagogy and assessment in the assessment instrument which privilege a certain kind of teaching. They assume a content-driven, lecture-based teaching model. We can see this most clearly in statements like: "the instructor presents class material clearly", "the class is well organized," and "the instructor appears to be knowledgeable in the subject." These statements would be inapplicable to many skills-based courses (e.g., writing courses, fine arts courses), experiential learning courses (e.g., field-work courses, foreign language courses), service learning courses, and so on. Conscientious students in these and other learning-centered courses that respond to emergent student needs and learning opportunities should give their instructors low marks (or perhaps "not applicable") on these teacher-focused survey items. In this way, SCEs tend to suppress pedagogical innovation and encourage faculty to teach to the evaluation. Moreover, as Seymour points out in *Talking about Leaving: Why Undergraduates Leave the Sciences* (*6*), faculty are afraid to violate the implied contract with students that they will teach by the traditional lecture/discussion/lab formula because of the well-known risk of declining SCE scores. Since SCEs play such a large role in rank, tenure and promotion decisions, the stakes are too high not to teach to the evaluation. SCEs thereby pressure faculty to use traditional teaching methods and provide a strong incentive not to tamper with—or even to think about—that pedagogy or the means of assessing it. Instead, faculty are rewarded for embracing an anachronistic pedagogy and for resisting efforts to change it or assess it meaningfully. Meanwhile, student engagement with, and enthusiasm for, the sciences suffers.

Finally, SCE's encourage abuse of the data they provide, further reducing the credibility of assessment. The results of standardized student evaluations are given numerically—usually in numbers rounded off to two decimal places. Except in classes with hundreds of students, the numbers to the right of the decimal point are meaningless when standard deviations and confidence intervals are taken into account. There is ample data in the literature on student course evaluations which demonstrates the unreliability of these numbers and that they should not be used to make significant distinctions. The IDEA (Individual Development and Educational Assessment) Center, for example, recommends dividing scores into four categories: (4) Outstanding, (3) Exceeds Departmental Standards, (2) Meets Departmental Standards, and (1) Below Departmental Standards (*7*). Yet chairs and administrators routinely make decisions about rank, tenure and promotion based on numbers to the right of the decimal point. (I'm not pointing fingers; we all know how overworked chairs and administrators are, and the fact is they rarely have any better measures to work with.) This inappropriate privileging of ranking and counting over published research on the meaning of evaluations demonstrates to faculty that those who have power over them are not really interested in pedagogy or its assessment—from which faculty logically conclude that they should not spend much time thinking about it either.

Disengagement may indeed be the most rational response to the dilemma that faculty face: they are powerless in relation to SCEs and their (ab)uses, yet they realize that their fates depend greatly on these flawed instruments. But the dissonance required by this strategy of detachment produces a volatile anxiety that turns easily to anger. Because most faculty have learned to teach to the evaluation, and by doing so keep their SCE scores where they need to be, most faculty can tolerate the use of SCEs even though they recognize the abuse because it costs them little. (Many faculty—especially those without strong backgrounds in assessment and/or statistics—are proud of their high SCE scores, believing that these scores demonstrate their prowess as teachers.) Moreover, fixing the problem would take time, money and effort; most faculty are willing conserve these valuable resources in return for their silence. However, when deans, chairs and other administrators ask faculty to spend more time and energy on assessment, the strategy of tacit tolerance no longer makes sense. Those increased demands on faculty time activate all the frustration and anger created by SCEs and fuel a backlash toward assessment in general.

To sum up then, the student course evaluations used at most schools and colleges do much to damage assessment of teaching and to disengage faculty from it. Because SCEs focus on instructor behaviors, they cannot help faculty assess their teaching or improve student learning. Because SCEs are inflexible, they cannot be adapted to specific course or departmental learning objectives. They inhibit innovation in teaching and assessment of teaching, and they encourage abuse of the data they provide. Faculty's experiences with SCEs and their uses drive the present resistance to assessment. There are alternatives to traditional SCEs that avoid these pitfalls.

The Original Student Assessment of Their Learning Gains (SALG) Instrument and Website

In contrast to typical SCEs, the SALG was developed in response to research on teaching and learning; it was designed specifically to overcome the weaknesses just discussed and to provide meaningful feedback to teachers about the value and efficacy of teaching. The SALG grew out of Elaine Seymour's 1996 work as co-evaluator of two NSF-funded chemistry consortia (ChemLinks and ModularCHEM) that developed and tested modular curricula and pedagogy for undergraduate chemistry courses. [PIs for ChemLinks Coalition: Making Chemical Connections, were Brock Spencer (Beloit College), James Swartz (Grinnell College), Sandra Laursen (Univeristy of Colorado), and David Oxtoby (University of Chicago). PIs for the ModularCHEM Consortium (Sweeping Change in Manageable Units: A Modular Approach to Chemistry Curriculum Reform) were C. Bradley Moore, Angelica Stacy, and Susan Kegley. The project director for ModularCHEM was Eileen Lewis.] Consortia faculty found that traditional student course evaluation instruments inaccurately measured students' learning gains and did not solicit useful formative feedback on innovative content and pedagogy. They faulted traditional instruments that (1) used satisfaction rather than learning as the basic criterion; (2) focused on facets of instructor performance (e.g., personal qualities) that were not central to learning outcomes; and (3) did not address the effectiveness of particular classroom methods. Furthermore, as other innovative teachers have found, consortia faculty with hitherto good classroom evaluation records tended to receive poorer evaluation scores for their innovative courses because students were initially uncomfortable with new teaching approaches. Despite these more negative evaluations, both faculty and teaching assistants observed that the quality of student work indicated gains in their conceptual understanding, skills, learning retention, and responsibility for learning (*8*). In essence, students punished innovative faculty with lower SCE scores *even though the students learned more in their classes*. These lower SCE scores led to failed tenure bids for four consortia faculty, despite their being able to present evidence that their courses had led to superior learning outcomes for their students. Thus, faculty have good reason to fear uninformed use of SCEs.

Following up on the faculty comments, evaluators interviewed random samples of students at 11 schools in the consortia about their learning experiences in introductory chemistry classes. The initial round of interviews included control classes at each institution so that evaluators could isolate the effects of pedagogical changes. A second round of interviews two years later allowed evaluators to assess differences between initial reactions to the new teaching methods and reactions to a more mature version of that pedagogy. The evaluators found that even in detailed interviews, student statements about what they "liked" or "disliked" about their classes or their teachers did not lead to information that was useful for gauging the relationship of teaching strategies and class activities to student learning. By contrast, when directly asked about their gains from specific aspects of classes, students gave detailed feedback about what had and had not enabled their learning. Students also gave useful advice on how to improve promising strategies that had worked imperfectly, and they offered thoughtful reasons for their assessments. It was clear that students were able to give detailed and nuanced answers when asked to focus on what they knew most about: how much and in what ways particular aspects of the class had helped them to learn (*9*).

These findings suggested that it would be possible to develop a valid student evaluation instrument that would allow faculty to assess their specific learning objectives and related course activities. Students' ability to provide detailed information about what had and had not helped them learn could guide pedagogical adjustments, affording a scientific foundation for faculty's efforts to improve their teaching. Seymour developed the Student Assessment of Learning Gains (SALG) instrument in 1997 to explore these possibilities and to provide a means of collecting evidence that would allow innovative and effective teachers defend their work.

The SALG instrument focuses exclusively on the degree to which a course has enabled student learning and was designed around two main principles: (1) teaching effectiveness should be measured in terms of stated goals, and (2) students have something valuable to tell instructors about what they learned in a class and what helped (and did not help) them learn it. Accordingly, the SALG asks students to assess and report on their own learning (in relation to course goals), and on the degree to which specific aspects of the course contributed to that learning. The original instrument had five overarching stem-questions. The first question focuses on the design and pedagogical activities of the course; the final four questions investigate students' progress toward specific course goals. The questions are:

1. How much did the following components of the course help you in your learning? (Categories included class activities, assignments, resources, etc.)
2. How well do you now feel that you understand each of the following? (Instructors insert those concepts that they consider most important.)
3. How much has this class added to your skills in each of the following? (Skills listed on the template included making quantitative estimates, finding trends in data, and writing technical texts.)
4. To what extent did you make gains in each of the following? (These questions address key course learning objectives, such as understanding the relationships between concepts, application of quantitative models to problem solving, or recognizing the relevance of a discipline to the world.)
5. How much of the following will you carry with you into other classes or your personal life? (The emphasis here is on the learning students think they are retaining and will continue to use.) (See Appendix 1: The Original SALG Instrument.)

The sub-items under each stem-question could be modified by instructors to adapt the instrument to the particular pedagogies and goals of their courses. The basic template encouraged such modification by including a couple of items that asked instructors to "insert disciplinary concept here." (How these characteristics of the SALG alleviate faculty complaints about SCEs will be discussed in the final section: Engaging Assessment.)

The prototype SALG instrument was piloted in three chemistry courses. In 1998, following its demonstrated success in those courses, the SALG instrument was used in 18 introductory modular chemistry classes or sections at 10 institutions connected to the chemistry consortia. (Results of these early studies are discussed below, in Research on SALG Use.)

This early success and positive feedback from users attracted support from other groups interested in reform of science education, especially the Wisconsin Center for Education Research's (WCER) National Institute for Science Education (NISE), headed by Robert Mathieu. Funding by NISE and Exxon Mobile paid for Susan Lottridge (formerly Daffinrud) to migrate the SALG from its original paper-and-pencil (and later Scantron) form to a web-based instrument. The SALG website that Lottridge created enabled instructors to modify a template version of the SALG instrument, deleting editing and adding questions to fit the course to the particulars of their courses. Once their students completed the instrument online, instructors could view raw data and simple statistics (frequency distributions, means, and standard deviations). The site was available between 1999 and 2008, and served more than 1,000 undergraduate instructors in more than 3,000 courses with over 65,000 students in a wide variety of STEM, social sciences and other disciplines.

The SENCER-SALG

In 2003, SENCER approached Seymour about using the SALG to assess their ambitious attempt to reform science education and increase civic engagement through service learning and other cutting-edge pedagogies. [SENCER (Science Education for New Civic Engagements and Responsibilities) is the flagship program of the National Center for Science and Civic Engagement. SENCER aims to improve science education, making it real and relevant to students by connecting it to complex, urgent and often unsolved, civic issues that directly affect students' lives. For more information, visit www.sencer.net.] This three-year collaboration between SENCER and members of Seymour's Ethnography and Evaluation Research group at the University of Colorado (Key Ethnography & Evaluation Research personnel included Carolie Coates, Heather Thiry, Tim Weston and Susan Lottridge) led to significant development of the original SALG instrument as well as a new website. The most visible innovation was the introduction of a pre-survey. (See Appendix 2: The SENCER-SALG Pre-Survey.) The pre-survey was designed to be given at the beginning of a term to assess students' baseline levels of confidence in their knowledge and skills, their interests relative to the subject and to collect basic demographic data. The first three questions were slight modifications of stem-questions 2, 3 and 5 from the original survey; questions about gender, ethnicity, major, GPA, etc. comprised the remainder of the survey. The post-survey of the SENCER-SALG also made slight modifications to those same stem-questions (2, 3 and 5) so that they would align with the pre-survey questions and could be used to measure gains in specific areas at the level of the specific student. (See Appendix 3: The SENCER-SALG Post-Survey.) The content of all questions was modified to reflect SENCER's specific goals and pedagogical proclivities. As in the original SALG, instructors were able to modify and add sub-items under the stem-questions. (Participants in the project that assessed the SENCER-SALG were asked not to modify any of the sub-items so that the reliability and validity of the instrument could be studied, but they were allowed to add sub-items to adapt the survey to their course.) The SENCER-SALG allowed greater variety of question formats, including the ability to present sets of items in table format. Other innovations included instructor-entered student IDs, which ensured that students used correct IDs and allowed individual scores to be more accurately matched across administrations; and monitoring of the amount of time students took to complete the surveys.

Between 2003 and 2008, more than 125 instructors and almost 16,000 students used the SENCER- SALG.

Another significant change prompted by SENCER was a new SALG website for evaluators developed by Susan Lottridge and Tim Weston. The evaluator site allows a program evaluator to create a core instrument and gather student data from a set of participating instructors across multiple courses and multiple institutions. Specifically, this site enables the evaluator of a faculty development program to (1) enter a list of participating instructors in order to link instructor data; (2) create pre- and post- versions of the SALG instrument targeted to the goals of the program; (3) enter a human subjects consent form for informing students of their rights in the study; (4) view the pre- and post- data collected by all of the participating instructors; and (5) create and administer a pre- and post- survey to the participating instructors. Participating instructors can add their own formative assessment questions to the program evaluation SALG. Students complete the SALG instrument as they would normally, except that prior to completing the instrument students are presented with an informed consent form and are given the option of participating (or not) in the project evaluation. The evaluator can access the student responses to the pre- and post- SALG instruments but not data from the instructor-added questions or from students who have chosen not to participate. The participating instructor has access to responses from all of the students on all of the questions.

This site has been in use by the SENCER evaluators since 2003 and has proven a powerful tool for conducting multi-site evaluation. For evaluators, the site permits almost immediate integration of data from geographically distant SENCER sites, which previously would have involved much more expensive and time-consuming site visits and mail surveys. Simultaneously, instructors have access to pre-/post- results, allowing them to analyze student learning gains and quickly make targeted changes to instruction. More than 70 instructors are using this version of the SALG.

SALG 2.0

By 2005, both the original SALG and SENCER-SALG websites were showing their age and feeling the effects of a vastly greater number of users than the sites were designed for. The sites were beginning to collapse under the weight of their own success, but the very reasons for that collapse argued strongly for the value of the SALG approach to course assessment. Late that year, the SALG Development Group (SDG) submitted a successful grant application to the National Science Foundation (NSF) to fund revisions to the instrument and website and to develop new websites for departments and program evaluators. [The SDG comprises Robert Mathieu—PI (University of Wisconsin—Madison), Stephen Carroll (Santa Clara University), Susan Lottridge (Pacific Metrics), Elaine Seymour (University of Colorado), and Tim Weston (University of Colorado).] The new site (www.salgsite.org) makes extensive use of the development work done for the SENCER evaluators and takes advantage of new research done on the SALG in particular and on student learning in general. SDG developed four new instrument templates for faculty users that were launched in summer 2008: two revised versions of the original SALG template instrument, a "Basic" version (shorter and more generic, designed for instructors who use traditional teaching methods) and a "Full" version (longer and reflecting a wider range of learning objectives and teaching methods), along with a Baseline instrument ("pre"-survey). [As before, faculty may also choose to start from an extant instrument, either one they previously created, or one created (and made publicly available) by someone else.] (See Appendix 4, Appendix 5, and Appendix 6: SALG 2.0 Basic Version, SALG 2.0 Full Version, and SALG 2.0 Baseline Instrument.) The Baseline survey has been modified to use different scales from the end-of-term SALG. (Modifications to the website architecture now make it possible to administer SALGs an unlimited number of times per term, so instructors can now use a SALG with a reduced question-set to assess learning at the mid-term and a full SALG at the end of the term.) It now uses scales that reflect absolute magnitude, whereas SALG instruments use gains scales. This shift reinforces the core principle that students have something valuable to tell instructors about what works for them and what does not by preventing instructors (and/or chairs and deans) from simply subtracting baseline scores from final scores. This latter practice implies that students are unable to accurately assess their own learning gains and that those gains are more accurately obtained through this pseudo-scientific procedure. Since both baseline and final scores are self-reported, there is little reason to believe that this subtraction results in a more accurate assessment of learning, while both the original research that led to the creation of the SALG and subsequent research on SALG use support the fact that students are fairly accurate assessors of their learning gains (*9*, *10*). The present approach has the added value that it allows instructors to understand the differential impact of their pedagogy on different sectors of the class: for example, it is possible to assess whether greater gains are made by those who initially ranked themselves as having low skills or those who asserted high skill levels. It continues to be possible to view differences in gains made by different genders and/or ethnicities, people in different age groups, etc. [The new SALG incorporates more aggressive measures to protect respondent anonymity. For example, when the responses to any demographic question total fewer than five within any category of response (e.g., fewer than five people identify themselves as female), the system randomly blanks that answer on five forms. Thus, an instructor is never allowed to link a set of survey responses with a particular person, even if they are unique with respect to that variable.]

The SDG revised the stem-questions and the sub-items of all templates to better reflect current research and best practices and to accommodate a greater variety of academic disciplines and teaching methods. Expanding the original pedagogy stem-question into six separate stem-questions sharpened the division between questions focusing on pedagogy and those focusing on learning goals. Homogenizing the response-scales within each section emphasized the unity of each section: the pedagogy section uses a helpfulness scale, the goals section uses a gains scale. The stem-questions focused on learning goals have been tightened and refocused to emphasize the difference between lower order learning goals (those focused on knowledge and skills) and higher order learning goals (those focused on changing attitudes and habits). A substantial expansion in the number of open-ended questions in SALG 2.0 reflects research showing that student comments are the most valuable form of feedback to faculty (*3*, *5*). The sub-items under the stem questions have also been revised to make them more focused and coherent. In addition to more open-ended questions, more items require instructors to fill in their specific academic disciplines, as well as concepts, activities, resources, etc. particular to the course. The items were also revised to be more leading and to encourage faculty to consider a variety of pedagogies. As before, faculty can edit existing instruments (including SALG instruments created by other users as well as their own previously-created instruments), add questions relevant to their courses, and save the resulting instruments for future use. They may also delete questions within limitations intended to preserve the exclusive learning-gains focus and format of the instrument.

The SDG also created templates, each built around a bank of alternative questions, to allow instructors to start from an instrument adapted to a distinctive class-type or pedagogy (e.g., lab classes, classes using of alternative pedagogies, or classes using advanced learning technologies). Questions with research-established gender relevance have been flagged so that faculty members can make themselves aware of the gender-climate in their classrooms and its effects on learning.

The new site includes more sophisticated analysis tools. (See Appendix 7: SALG 2.0 Analysis Page.) As before, instructors can view the number of responses, frequency distributions, means, modes and standard deviations. (See Appendix 8: SALG 2.0 Scale-Question Detail.) The new package allows instructors to combine the results of multiple instruments, run crosstab analyses, and do longitudinal analyses. An entire survey can be downloaded as a pre-formatted Excel file that includes a cover sheet, a copy of the instrument, a table of the raw data, and a statistical summary with graphs. The analysis package includes a basic text-data analysis tool that allows an instructor to code responses to open-ended questions on the fly and subject them to statistical analyses. (See Appendix 9: SALG 2.0 Open-Ended Question Detail.)

Between June 2008—when the new site went live—and June 2009, over 2100 instructors have created SALG accounts. They have created and administered over 1500 surveys to almost 35,000 students (mostly in STEM disciplines). Most of the feedback about the revisions has been positive, and the site continues to grow rapidly. As part of the ongoing testing and revision process, Weston and Carroll have conducted several usability studies at universities around the country over the past three years. Major revisions to the user interface based on their research have made the SALG progressively more transparent and easier to use.

The current SALG revision project also includes two sites that will become available sometime in 2009, one for departments and one for program evaluators. The department site allows a department to collect data across multiple courses about students' progress toward the department's learning goals. Once the relevant committee has made a collegial decision about the department's learning goals (overall or as applied to particular courses), the chair or a designated administrator can create and distribute to appropriate faculty a SALG instrument adapted to those learning goals. The administrator has the usual freedom to add, delete and/or edit sub-items and to add stem-questions to any template they choose to start from. However, the administrator also has the ability to lock certain questions so that any faculty member who uses this departmental instrument cannot delete or edit them. Obviously, the administrator can seed the document with "recommended" questions as well, but individual faculty are free to delete or modify those—only the locked questions are unchangeable. The department administrator creates a distribution list by typing (or pasting) in a list of email addresses. When a faculty members with those email addresses log into the SALG website, they are notified of their option to use the departmental template. As with other SALGs, a faculty member is free to add, delete and/or edit any question that has not been locked by the administrator.

When the survey closes, administrators and faculty are shown different views of the data. Administrators see only the results of the locked questions. Faculty members see all the results. This differential data routing is intended to allow the administrator to collect data relevant to departmental learning objectives (needed, for example, by accreditation agencies, deans offices, etc.) without impeding instructors' ability to adapt their assessment instruments to the goals and methods of their particular courses. The differential routing is also intended to protect faculty's freedom to experiment with new pedagogies without anyone looking over their shoulders.

The department site includes a robust set of analytical tools that allow department administrators to look at trends in data by course, by learning objective, by term, by faculty member, or by student. Administrators are allowed to upload student data (e.g., grades, demographic information) into the system that allows them to track students over time and to conduct more finely grained analyses than are possible on the instructor site. The department site is currently being beta-tested.

The program evaluator site draws heavily on the SENCER-SALG evaluator site. Like that site, its primary purpose is to allow data collection across courses and across multiple institutions. Following the SENCER-SALG model, it allows researchers to deliver human subjects consent forms directly to the student immediately prior to their completion of the survey and it allows evaluators to create and deliver surveys to participating faculty. In other respects, the evaluator site operates essentially the same way as the department site: it allows uploads of student data and lists of participating faculty email addresses and it includes the same mechanisms for locking questions. The controls over stem-questions and response scales will be somewhat relaxed on the evaluator site to allow greater flexibility for researchers. This has already proved attractive to a research team from the University of Colorado, who has developed an instrument for assessing undergraduate research programs—the Undergraduate Research Student Self-Assessment (URSSA)—which will be housed on the new site. A beta version of the URSSA is already up and running on the instructor SALG site [The URSSA is discussed in *CUR. QUART.* **2009**, *29* (3)]. SENCER has also made a commitment to using the new evaluator site and has commissioned a new SENCER-SALG to be developed for it. The program evaluator site is still under construction.

Research on SALG Use

The most important research on the SALG concerns the instrument's ability to provide valid and reliable feedback to faculty about student learning. In 1998, the Exxon Education Foundation funded a panel test of the SALG instrument in which a set of common questions was used in 18 introductory modular chemistry classes or sections at 10 institutions (*9*). The high and low means for particular SALG items correlated strongly with evaluation interview data from these classes. Some areas of student-reported gain that were strong from both data sources (and significantly stronger in the modular class than in the traditional class) were: seeing the connections between ideas, the relevance of chemistry to the real world, a better understanding of what science is and how it is done, retaining and being able to apply what they had learned, and feeling well prepared for the next chemistry class. Problem areas identified by the SALG instrument analysis and in the interview data were: ongoing student difficulties in writing papers or giving oral explanations of their work, and in learning when too fast a pace was set (*8*). These initial tests suggested that the *content validity* of the SALG questions is good.

The instrument's validity and reliability were further tested over several iterations of an innovative astronomy course at the University of Colorado at Boulder (2000-2001) and as part of the evaluation of the first SENCER project (2003-2005). The validity and reliability of the instrument were assessed in multiple ways: (1) By examining student responses to the surveys compared with interview findings. The core items that ask students to rate different course activities in terms of *how much they helped with their learning* were both valid and reliable in ranking high- and low-efficacy activities. (2) By establishing the relationship between the SALG results and other measures of learning gains. When students were asked to rate their understanding of specific concepts in astronomy, self-ratings correlated moderately (r=0.45) with final grades. [This result accords with other research about the relationship of self-assessment and direct assessment. In a large-scale study of student self assessment, Falchikov and Boud (*11*) conducted a meta-analysis of 57 separate studies of the relationship between faculty and student ratings of student performance. The researchers found that (in absolute terms) students tended to rate themselves higher than faculty rated the same student performances. The average correlation between faculty and student ratings was r =0.39, a finding very close to our result. Final grades measure something other than learning gains. Because final grades are supposed to reflect students' absolute knowledge of the material they are tested on, those grades will be substantially affected by the learning students have done prior to enrolling in the course. Students, for example, who have strong backgrounds in physics and those who have taken other astronomy courses, will have to learn less to earn a certain grade than a student with a less relevant background. Final grades also include factors that may not be related to learning, factors like turning in work on time, being present in class for quizzes, etc. These differences between grades and learning gains contribute to a weaker correlation than one would expect between SALG scores and an objective measure more directly focused on learning.] In the SENCER program, SALG measures of *confidence in general science skills*, *interest in science activities* and *civic* *engagement* had only low correlations (r=0.3) with grades and final test scores for students in chemistry and biology courses. (The caveat about the differences between learning gains and final grades and test scores applies here as well. Two other factors also likely contribute to this lower correlation. These SENCER courses were lower-division, introductory science courses, which by definition will include a larger-than-average number of students with low confidence in their science skills and low interest in science. For this population, grades and test scores often remain low despite significant learning gains. Moreover, Falchikov and Boud's (11) data show that non-science students and students in introductory courses self-assess less accurately than do science students and upper-division students.) (3) The factorial structure of both the SALG and SENCER-SALG conformed to the expectations of the survey developers: factors for improvements in science skills and increased interest in the discipline were moderately correlated; civic engagement (an important SENCER objective) was largely independent of skills and interest. (4) By analysis of survey and interview data provided by participating instructors. Of the 39 SENCER instructors who responded to a survey about uses of SALG feedback 34 (87%) reported that they had made substantive changes to their courses using the feedback gathered with the SENCER-SALG instrument. All but three of these instructors reported that the SALG responses provided *qualitatively different and more useful student feedback* than their traditional evaluations because the student responses were very specific and focused on their own learning (*12*).

This finding that the SALG provided different and more useful feedback than traditional SCEs was confirmed by other studies. In a study by Daffinrud and Demont (*13*), users reported that the specificity and course relevance of SALG questions make students' responses particularly useful in adjusting aspects of their pedagogy. Engineering faculty reported that: "In our experience, the instructors were thankful to receive such good feedback relative to the way their course material is being received." The report authors cited numerous examples of course improvements that were prompted and informed by specific student comments.

Engaging Assessment

Unlike typical SCEs, the SALG furnishes a number of paths which encourage faculty to engage positively and actively with teaching and with assessment of learning. First, and most importantly, the SALG measures student's *learning gains* and it provides valid, reliable formative feedback that is immediately and directly useful to faculty. The fact that it provides specific, useful information that helps faculty improve their teaching is almost certainly the single biggest way in which the SALG and SENCER-SALG increase faculty engagement. Users report that the specificity stimulates them to think about their goals, their pedagogies and the relationships between them. This leads to adjustments, experiments, and further assessment to see if those adjustments worked. The result is continuously improved teaching.

The SALG and SENCER-SALG approach place instructors squarely at the center of the formative evaluation process. It seeks to maximize interactivity, flexibility and instructor control. Everything about the SALG except the underlying architecture that gives it its identity is customizable, adaptable to the unique goals and pedagogies of an individual instructor. The SALG can be easily modified to embody the learning goals of a variety of interested parties, from the college all the way through the department to the individual instructor. The SENCER-SALG in particular sets a powerful example: its thorough-going modification of the SALG questions to suit its own particular goals and pedagogies models what is possible and sets a powerful example that encourages emulation. Indeed, as the SALG has evolved, it has grown to *require* that customization by including more and more questions that must be modified (or deleted). This flexibility not only promotes engagement by offering faculty control of their own instruments, faculty create the questions and instruments by which they assess their students' learning. Most importantly, the SALG forces faculty to make decisions about what their pedagogical goals really are and about how their teaching methods support those goals. My own experience as a faculty developer reminds me that this is the most difficult engagement to make yet also the most powerful, because once made it tends to be self-perpetuating. Once faculty become curious about their pedagogy, once they begin to study how their methods affect student learning, they are usually hooked for life.

The SALG and SENCER-SALG do not presume or privilege any particular pedagogy, but rather promote pedagogical innovation and diversity of pedagogical approaches. The arrangement of the sub-items in the Full version of the SALG template is designed to expose faculty members to a variety of cutting-edge teaching methods. An Alternative Pedagogies template embeds even more of these innovative teaching methods. In fact, the very reason these alternative templates exist is to allow instructors to quickly and easily adapt their instruments to the contours of different types of courses and their corresponding pedagogies (e.g., lab courses, studio arts courses). The differential data routing built into the department and evaluator sites likewise protects and nurtures innovation by ensuring that each constituency gets the information it needs and no more. It protects the freedom of faculty to fail without fear of repercussions from above—a necessary precondition for sustainable innovation.

Finally, while the SALG does provide numerical responses that can be easily ranked, its flexibility virtually guarantees that a great variety of instruments will be in use on a given campus, within a given department and even among a given instructor's various courses. This diversity of instruments makes it much harder to abuse those numerical results. In an ironic twist, that very diversity makes it easier to compare faculty assessment results meaningfully. If every faculty member on campus uses an assessment instrument that is tailored to his or her specific learning objectives and pedagogical methods, the scores they receive will evaluate their progress toward their own self-determined objectives. If they are using a department instrument, those scores will also reflects students' progress toward mutually agreed-upon departmental learning goals and objectives. This is a much fairer way to compare faculty than using an instrument that measures their behaviors relative to a standardized pedagogy which varies greatly in its relevance to their discipline, course-type, teaching style and purposes.

The SALG's department and evaluator site offer capacities for faculty engagement that transcend the possibilities of typical SCEs. Both offer the possibility of aligning goals, objectives and outcomes across a relevant constituency, whether that be a college, a department, or an experimental working group. Creating this kind of consistency allows interested parties to look at learning that happens beyond the classroom: the learning that results from the curriculum of a major, for example, or from an undergraduate research experience. Consistency of assessment measures with goals and objectives also promotes meaningful research on teaching and learning, another avenue of engagement. And last, but most importantly, consistency of this type assures faculty that assessment is valuable to faculty, is taken seriously and is academically respectable. This too adds an incentive to become engaged.

The most important result of faculty's increased engagement with assessment is improved teaching and learning. Several studies confirm that the SALG provides useful data that stimulate faculty to make meaningful changes to their courses that improve student learning. However, the SALG has one more trick up its virtual sleeve. *The design of the SALG promotes student learning directly*. The fact that the SALG includes both pre- and post- class surveys that make the course goals explicit models best practices in teaching. It puts the course goals in front of the students at the beginning of the course and asks students to assess their initial competence in relation to them. It then puts those same goals in front of the students at the end of the course and asks students to assess the learning gains they have made relative to those goals. In addition, the end-of-term SALG asks students to evaluate which teaching methods, class activities, etc. were most helpful in stimulating those learning gains. By asking students to reflect repeatedly on their own learning gains and on what is responsible for provoking those gains, we help students develop stronger metacognitive skills and turn them into more intentional learners. As students become more active, more critical, more responsible learners, they become active partners in our educational enterprise. Not only does this help us become better teachers on the practical level by saving us time and resources, it creates a self-sustaining feedback loop: more intentional learners provide more accurate and more sophisticated feedback on what helps them learn, which guides faculty as they refine their goals and teaching strategies, which in turn become more effective, which results in even more critical and intentional learners. The highly directed content of the SENCER-SALG channels that increased intentionality, critical thinking, and responsibility to promote civic engagement and accountability as well as engagement with science.

Conclusion

Clearly, student self-reports regarding which aspects of a course have enabled their learning—and to what extent—is not a complete indicator of actual learning. What the SALG does is pinpoint with demonstrated accuracy those aspects of a course that are working well for students, and obtain advice from students on how to improve course activities. The formal evidence attests to the validity and reliability of the data; the high and growing number of users, and the increasing number of their publications and presentations, attests to the utility of the SALG concept. When the SALG is combined with other measures of learning, such as student performance on skills inventories, tests and/or assignments, it offers faculty and evaluators a powerful triangulation on both the extent and causes of student learning. As such, it constitutes a vastly preferable alternative to traditional student course evaluations, one that makes the primary means of course assessment rational, effective and valuable to faculty.

The word *assessment* comes from the Latin *assidere* (or *ad sedere*), which means to sit beside someone: assessment was originally construed as cooperative and supportive in nature. To create a culture that values assessment and is willing to use it collaboratively to support improved teaching, we need to change the most formative means by which assessment is practiced. The SALG and SENCER-SALG are powerful, flexible, free tools, which overcome the liabilities of traditional student course evaluations and engage faculty actively and positively in teaching and learning and their assessment (www.salgsite.org). They are valid, reliable instruments, firmly grounded in more than a decade of research, that provide faculty with useful feedback that helps them make meaningful improvements in their teaching and in their students' learning. They are adaptable to every discipline, every type of course and every teaching style. They promote individualization, yet also provide means of collecting data relevant to common purposes. Most importantly, they are powerful teaching tools themselves, tools that allow our students to sit beside us, transforming them into more intentional learners, more critical and active participants in their own education. I suspect that creating active, responsible, self-guided learners has something to do with why some of us chose this career in the first place.

Appendix 1: The Original SALG Instrument

Student Assessment of Learning Gains

Instrument

SALG Original Version:

Go to your List of Courses Log Out Go to your Course Options

Go back

Your students will see the questions as they appear on this page.

Instructions:
Check one value for each question on each scale. If the question is not applicable, check 'NA'. You may add a comment for any item in the text box at the end of the survey.

Q1: How much did each of the following aspects of the class help your learning?

	NA	No help	A little help	Moderate help	Much help	Very much help
A. The way in which the material was approached	○	○	○	○	○	○
B. How the class activities, labs, reading, and assignments fit together	○	○	○	○	○	○
C. The pace at which we worked	○	○	○	○	○	○
D. The class activities	**NA**	**No help**	**A little help**	**Moderate help**	**Much help**	**Very much help**
1. Class presentations (including lectures)	○	○	○	○	○	○
2. Discussion in class	○	○	○	○	○	○
3. Group work in class	○	○	○	○	○	○
4. Hands-on class activities	○	○	○	○	○	○
5. Written lab instructions	○	○	○	○	○	○
6. Lab organization	○	○	○	○	○	○
7. Teamwork in labs	○	○	○	○	○	○
8. Lab reports	○	○	○	○	○	○
E. Tests, graded activities and assignments	**NA**	**No help**	**A little help**	**Moderate help**	**Much help**	**Very much help**
1. Opportunities for in-class review	○	○	○	○	○	○
2. The number and spacing of tests	○	○	○	○	○	○
3. The fairness of test content	○	○	○	○	○	○
4. The mental stretch required of us	○	○	○	○	○	○
5. The grading system used	○	○	○	○	○	○
6. The feedback we received	○	○	○	○	○	○
F. Resources	**NA**	**No help**	**A little help**	**Moderate help**	**Much help**	**Very much help**
1. The text	○	○	○	○	○	○
2. Other reading materials	○	○	○	○	○	○
3. use made of the WWW in this class	○	○	○	○	○	○
G. The information we were given about	**NA**	**No help**	**A little help**	**Moderate help**	**Much help**	**Very much help**
1. Class activities for each week	○	○	○	○	○	○
2. How parts of the classwork, labs, reading, or assignments related to each other	○	○	○	○	○	○
3. The grading system for the class	○	○	○	○	○	○
H. Individual support as a learner	**NA**	**No help**	**A little help**	**Moderate help**	**Much help**	**Very much help**
1. The quality of contact with the teacher	○	○	○	○	○	○
2. The quality of contact with the Tas	○	○	○	○	○	○
3. Working with peers outside of class	○	○	○	○	○	○
K. The way this class was taught overall	○	○	○	○	○	○

Q2: As a result of your work in this class, how well do you think that you now understand each of the following?

	NA	Not at all	A little	Somewhat	A lot	A great deal
1. chemistry concept 1	○	○	○	○	○	○
2. chemistry concept 2	○	○	○	○	○	○
3. chemistry concept 3	○	○	○	○	○	○

Q3: How much has this class added to your skills in each of the following?

	NA	Nothing	A little	Somewhat	A lot	A great deal
1. Solving problems	○	○	○	○	○	○
2. Writing papers	○	○	○	○	○	○
3. Designing lab experiments	○	○	○	○	○	○
4. Finding trends in data	○	○	○	○	○	○
5. Critically reviewing articles	○	○	○	○	○	○
6. Working effectively with others	○	○	○	○	○	○
7. Giving oral presentations	○	○	○	○	○	○

Q4: To what extent did you make gains in any of the following as a result of what you did in this class?

	NA	Not at all	A little	Somewhat	A lot	A great deal
1. Understanding the main concepts	○	○	○	○	○	○
2. Understaning the relationship between concepts	○	○	○	○	○	○
3. Understanding how ideas in this class relate to those in other science classes	○	○	○	○	○	○
4. Understanding the relevance of this field to real world issues	○	○	○	○	○	○
5. Appreciating this field	○	○	○	○	○	○
6. Ability to think through a problem or argument	○	○	○	○	○	○
7. Confidence in your ability to do this field	○	○	○	○	○	○
8. Feeling comfortable with complex ideas	○	○	○	○	○	○
9. Enthusiasm for subject	○	○	○	○	○	○

Q5: How much of the following do you think you will remember and carry with you into other classes or aspects of your life?

	NA	Not at all	A little	Somewhat	A lot	A great deal
1. Understanding the main concepts	○	○	○	○	○	○

Q6: Add comments below

This site was created with funding courtesy of the The ExxonMobil Foundation and the following National Science Foundation-funded projects:

New Traditions (NT)
ChemLinks
ModularChemistry (MC2)

The National Institute for Science Education

The AAC&U SENCER Institutes

Appendix 2: The SENCER-SALG Pre-Survey

Student Assessment of Learning Gains

View Instrument

National Center for Science and Civic Engagement SENCER Spring 2006

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The students enrolled in the faculty participants' courses will see the questions as they appear on this page.

1. Presently, I am CONFIDENT I can ...

1. Discuss scientific concepts with my friends or family	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
2. Think critically about scientific findings I read about in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
3. Determine what is -- and is not -- valid scientific evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
4. Make an argument using scientific evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
5. Determine the difference between science and "pseudo-science"	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
6. Interpret tables and graphs	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
7. Understand mathematical and statistical formulas commonly found in scientific texts	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
8. Find scientific journal articles using library/internet databases	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
9. Extract main points from a scientific article and develop a coherent summary	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
10. Give a presentation about a science topic to your class	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
11. Obtain scientific data in a laboratory or field setting	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
12. Understand how scientific research is carried out	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
13. Pose questions that can be addressed by collecting and evaluating scientific evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

14. Organize a systematic search for relevant data to answer a question	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
15. Write reports using scientific data as evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
16. Understand scientific processes behind important scientific issues in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
17. Understand the science content of this course	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

2. Presently, I am interested in ...

1. Discussing science with friends or family	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
2. Reading about science and its relation to civic issues	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
3. Reading articles about science in magazines, journals or on the internet	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
4. Taking additional science courses after this one	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
5. Majoring in a science-related field	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
6. Exploring career opportunities in science	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
7. Joining a science club or organization	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
8. Attending graduate school in a science-related field	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
9. Teaching science	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested

3. In the past year, how often have you ...

1. Discussed a science-related issue informally	NA	Never	Once	Twice	Three times	More than three times
2. Discussed a civic or political issue informally	NA	Never	Once	Twice	Three times	More than three times
3. Read a science-related magazine not required by class	NA	Never	Once	Twice	Three times	More than three times
4. Written a letter or emailed a public official about a civic or political issue	NA	Never	Once	Twice	Three times	More than three times
5. Written a letter or emailed a public official about a science-related issue	NA	Never	Once	Twice	Three times	More than three times
6. Talked with a public official about a civic or science-related issue	NA	Never	Once	Twice	Three times	More than three times
7. Debated or offered public comment on a scientific issue	NA	Never	Once	Twice	Three times	More than three times
8. Debated or offered public comment on a civic or political issue	NA	Never	Once	Twice	Three times	More than three times
9. Attended a meeting, rally, or protest about a civic or political issue	NA	Never	Once	Twice	Three times	More than three times
10. Written a letter to the editor about a civic or political issue	NA	Never	Once	Twice	Three times	More than three times
11. Written a letter to the editor about a science-related issue	NA	Never	Once	Twice	Three times	More than three times

4. Please tell us why you are taking this course.

1. It is required and I am interested in the topic of the course	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2. It is required but I am not interested in the topic of the course	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3. It is not required but I am interested in the topic of the course	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
4. The course fits my schedule	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
5. It is a prerequisite for another course	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
6. I heard good things about the teacher	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
7. I was drawn to a science course that promised to address civic issues	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
8. I was drawn to a course that promised to apply science to real world issues	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
9. I did not know that the course addressed civic topics	NA	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

5. What is your gender?

- a. Male
- b. Female

6. What is your age group?

- a. 18 or younger
- b. 19-21
- c. 22-30
- d. 31-40
- e. 41-49
- f. Over 50

7. What is your ethnic designation?

- a. White/Caucasian
- b. Black/African American
- c. Hispanic or Latino/not White
- d. Native American
- e. Asian or Pacific Islander
- f. Other

8. What best characterizes your status as having selected a discipline-based major in college?

- a. Science major
- b. Not a science major
- c. Undecided at this time
- d. Plan on becoming a science major
- e. Plan on becoming a major in another area

9. What level are you at in college?

- a. Freshman
- b. Sophomore
- c. Junior
- d. Senior
- e. Post-graduate
- f. Not a degree-seeking student at this time

10. Are you in a teacher preparation program?

- a. Yes
- b. No
- c. Undecided at this time

11. What is your current GPA in a system that assumes a 4.00 as an A (highest score possible)?

- a. 4.00-3.60
- b. 3.01-3.59
- c. 2.51-3.00
- d. 2.01-2.50
- e. 2.00 or lower

12. How many college-level science courses have you enrolled in so far -- including this one?

- a. One science course
- b. Two or three science courses
- c. Four to five science courses
- d. Six to seven science courses
- e. More than eight science courses

submit data

This site was created with funding courtesy of the The ExxonMobil Foundation and the following National Science Foundation-funded projects:

New Traditions (NT)
ChemLinks
ModularChemistry (MC2)

The National Institute for Science Education

Appendix 3: The SENCER-SALG Post-Survey

Student Assessment of Learning Gains

View Instrument

National Center for Science and Civic Engagement SENCER Spring 2006

Log Out

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The students enrolled in the faculty participants' courses will see the questions as they appear on this page.

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA."

Course focus on:

1. Addressing real-world issues	NA	No help	A little help	Moderate help	Much help	Very much help
2. Interplay between science and civic issues	NA	No help	A little help	Moderate help	Much help	Very much help
3. Gathering scientific data in labs or in the field	NA	No help	A little help	Moderate help	Much help	Very much help
4. Analyzing scientific data	NA	No help	A little help	Moderate help	Much help	Very much help
5. Using scientific methods	NA	No help	A little help	Moderate help	Much help	Very much help
6. Learning scientific facts	NA	No help	A little help	Moderate help	Much help	Very much help
7. Learning how real science is done	NA	No help	A little help	Moderate help	Much help	Very much help
8. Summarizing scientific results	NA	No help	A little help	Moderate help	Much help	Very much help
9. Learning from the textbook	NA	No help	A little help	Moderate help	Much help	Very much help

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA." (continued)

The class activities:

1. Presentations/lectures from course instructor(s)	NA	No help	A little help	Moderate help	Much help	Very much help
2. Discussions in class	NA	No help	A little help	Moderate help	Much help	Very much help
3. Group work in class	NA	No help	A little help	Moderate help	Much help	Very much help
4. Individual work in class	NA	No help	A little help	Moderate help	Much help	Very much help
5. Lab activities	NA	No help	A little help	Moderate help	Much help	Very much help
6. Computer-based work	NA	No help	A little help	Moderate help	Much help	Very much help
7. Media such as videos, film or slides	NA	No help	A little help	Moderate help	Much help	Very much help

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA." (continued)

Graded activities and assignments:

1. Completing written assignments (individual or group)	NA	No help	A little help	Moderate help	Much help	Very much help
2. Preparing for oral presentations (individual or group)	NA	No help	A little help	Moderate help	Much help	Very much help
3. Participating in group/team projects	NA	No help	A little help	Moderate help	Much help	Very much help
4. Receiving in-class review before tests	NA	No help	A little help	Moderate help	Much help	Very much help
5. Receiving feedback on our work	NA	No help	A little help	Moderate help	Much help	Very much help

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA." (continued)

Resources

1. Studying course text	NA	No help	A little help	Moderate help	Much help	Very much help
2. Studying other readings	NA	No help	A little help	Moderate help	Much help	Very much help
3. Studying course website	NA	No help	A little help	Moderate help	Much help	Very much help

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA." (continued)

External class activities:

1. Studying individually	NA	No help	A little help	Moderate help	Much help	Very much help
2. Studying with a partner	NA	No help	A little help	Moderate help	Much help	Very much help
3. Studying with a group	NA	No help	A little help	Moderate help	Much help	Very much help
4. Receiving help from a TA	NA	No help	A little help	Moderate help	Much help	Very much help
5. Receiving help from the instructor outside of class	NA	No help	A little help	Moderate help	Much help	Very much help

1. HOW MUCH did each of the following HELP YOUR LEARNING? If your course does not include an activity, please choose "NA." (continued)

The information we were given about:

1. How the different parts of the course, such as class work, labs readings, or other assignments relate to each other	NA	No help	A little help	Moderate help	Much help	Very much help

2. What one thing would you do to improve this course?

3. What course activity helped you learn the most? Describe why it helped you learn.

4. After finishing this class, I am CONFIDENT I can...

1. Discuss scientific concepts with my friends or family	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
2. Think critically about scientific findings I read about in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
3. Determine what is -- and is not -- valid scientific evidence in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
4. Make an argument using scientific evidence to friends or family	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
5. Determine the difference between science and "pseudo-science" in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
6. Interpret tables and graphs	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
7. Understand mathematical and statistical formulas commonly found in scientific texts	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
8. Find scientific journal articles using library/internet databases	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
9. Extract main points from a scientific article and develop a coherent summary	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
10. Give a presentation about a science topic to your class	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
11. Obtain scientific data in a laboratory or field setting	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
12. Understand how scientific research is carried out	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
13. Pose questions that can be addressed by collecting and evaluating scientific evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
14. Organize a systematic search for relevant data to answer a question	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
15. Write reports using scientific data as evidence	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
16. Work with others collaboratively on a scientific project	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
17. Apply scientific information to social concerns	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
18. Understand scientific processes behind important scientific issues in the media	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

19. Understand the science content of this course	NA	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

5. Are there any skills you believe you gained from the course that are not listed above?

6. After finishing this class, I am INTERESTED in...

1. Discussing science with friends or family	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
2. Reading about science and its relation to civic issues	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
3. Reading articles about science in magazines, journals or on the internet	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
4. Taking additional science courses after this one	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
5. Majoring in a science-related field	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
6. Exploring career opportunities in science	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
7. Joining a science club or organization	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
8. Attending graduate school in a science-related field	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
9. Teaching science	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
10. Participating in an internship with a scientific organization or laboratory	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
11. Learning more about other scientific disciplines	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
12. Volunteering for science-related community service	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
13. Participating in non-formal science education at a museum or a school	NA	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested

7. Are there any other activities related to science that you are interested in?

8. After finishing this class, I am more likely to...

1. Discuss a science-related issue informally	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
2. Discuss a civic or political issue informally	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
3. Read a science-related magazine not required by class	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
4. Write a letter or email a public official about a civic or political issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
5. Write a letter or email a public official about a science-related issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
6. Talk with a public official about a civic or science-related issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
7. Debate or offer public comment on a scientific issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
8. Debate or offer public comment on a civic or political issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
9. Attend a meeting, rally, or protest about a civic or political issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
10. Write a letter to the editor about a civic or political issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
11. Write a letter to the editor about a science-related issue	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
12. Join a science-related civic organization	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
13. Participate in science-related civic education	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
14. Do an internship at a civic organization	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
15. Participate in one-time civic events such as walk-a-thons	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely
16. Vote in elections	NA	Not more likely	A little more likely	Somewhat more likely	Much more likely	Extremely more likely

9. Are there any other civic activities you plan on doing during the coming year?

submit data

This site was created with funding courtesy of the The ExxonMobil Foundation and the following National Science Foundation-funded projects:		
New Traditions (NT) ChemLinks ModularChemistry (MC2)	The National Institute for Science Education	

Appendix 4: SALG 2.0 Basic Version

English

PREVIEW INSTRUMENT #9864

Sign out

This page allows to you to preview an instrument. From this page, you can make a copy the entire instrument without changes, copy questions from the instrument, or make a copy of the instrument with changes.

My personal page
Reuse this instrument
Copy questions from this instrument
Edit this instrument

- **Status: Editing** [?]
- Instructor: Stephen Carroll
- Institution: Santa Clara University
- Department: English
- Course:
- Semester:
- Description:
- Survey start date: (not set)
- Survey end date: (not set)
- Visibility: Default [?]

Instructions to students:

Teachers value students' feedback and take it into account when improving their courses. Please be as precise as you can in your answers. Please choose "not applicable" for any activity you did not do. You may find one or more questions at the end of each section that invite an answer in your own words. Please comment candidly, bearing in mind that future students will benefit from your thoughtfulness. Remember that this is an anonymous survey: your teacher will never know what any individual student has written.

You may see the following note next to some questions:

"***D***" — Department question. The department head can view the responses to these questions.

The Class Overall

1. HOW MUCH did the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
1.1 The instructional approach taken in this class	○	○	○	○	○	○
1.2 How the class topics, activities, reading and assignments fit together	○	○	○	○	○	○
1.3 The pace of the class	○	○	○	○	○	○
1.4 Please comment on how the INSTRUCTIONAL APPROACH to this class helped your learning.						

Class Activities

2. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
2.1 Attending lectures	○	○	○	○	○	○
2.2 Participating in discussions during class	○	○	○	○	○	○
2.3 Specific Class Activities	no help	a little help	moderate help	much help	great help	not applicable
2.3.1 Class Activity 1 [Fill in]	○	○	○	○	○	○
2.3.2 Class Activity 2 [Fill in]	○	○	○	○	○	○
2.3.3 Class Activity 3 [Fill in]	○	○	○	○	○	○
2.4 Please comment on how the CLASS ACTIVITIES helped your learning.						

Assignments, graded activities and tests

3. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
3.1 Graded assignments (overall) in this class	○	○	○	○	○	○
3.2 Specific graded assignments	no help	a little help	moderate help	much help	great help	not applicable
3.2.1 Assignment 1 [Fill in]	○	○	○	○	○	○
3.2.2 Assignment 2 [Fill in]	○	○	○	○	○	○
3.3 The number and spacing of tests	○	○	○	○	○	○
3.4 The fit between class content and tests	○	○	○	○	○	○
3.5 The feedback on my work received after tests or assignments	○	○	○	○	○	○
3.6 Please comment on how the GRADED ACTIVITIES AND TESTS helped your learning.						

Class Resources

4. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
4.1 The textbook	○	○	○	○	○	○
4.2 Other reading materials	no help	a little help	moderate help	much help	great help	not applicable
4.2.1 Reading material 1 [Fill in]	○	○	○	○	○	○
4.2.2 Reading material 2 [Fill in]	○	○	○	○	○	○
4.3 Online notes or presentations posted by instructor	○	○	○	○	○	○
4.4 Please comment on how the RESOURCES in this class helped your learning.						

The information you were given

5. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
5.1 Explanation of how the class topics, activities, reading and assignments related to each other						
5.2 Explanation given by instructor of how to learn or study the materials						
5.3 Please comment on HOW the INFORMATION YOU RECEIVED about the class helped your learning.						

Support for you as an individual learner

6. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
6.1 Interacting with the instructor during class						
6.2 Interacting with the instructor during office hours						
6.3 Working with teaching assistants outside of class (e.g., recitation, office hours)						
6.4 Working with peers outside of class (e.g., study groups)						
6.5 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class.						

Your understanding of class content

7. As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
7.1 The main concepts explored in this class						
7.2 The relationships between the main concepts						
7.3 The following concepts that have been explored in this class	no gains	a little gain	moderate gain	good gain	great gain	not applicable
7.3.1 (Concept 1) [Fill in]						
7.3.2 (Concept 2) [Fill in]						
7.4 How ideas from this class relate to ideas encountered in other classes within this subject area						
7.5 Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class.						

Appendix 5: SALG 2.0 Full Version

English

PREVIEW INSTRUMENT #9865

Sign out

This page allows to you to preview an instrument. From this page, you can make a copy the entire instrument without changes, copy questions from the instrument, or make a copy of the instrument with changes.

My personal page
Reuse this instrument
Copy questions from this instrument
Edit this instrument

- **Status: Editing** [?]
- Instructor: Stephen Carroll
- Institution: Santa Clara University
- Department: English
- Course:
- Semester:
- Description:
- Survey start date: (not set)
- Survey end date: (not set)
- Visibility: Default [?]

Instructions to students:

Teachers value students' feedback and take it into account when improving their courses. Please be as precise as you can in your answers. Please choose "not applicable" for any activity you did not do. You may find one or more questions at the end of each section that invite an answer in your own words. Please comment candidly, bearing in mind that future students will benefit from your thoughtfulness. Remember that this is an anonymous survey: your teacher will never know what any individual student has written.

You may see the following note next to some questions:
"***D***" — Department question. The department head can view the responses to these questions.

The Class Overall

1. HOW MUCH did the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
1.1 The instructional approach taken in this class	○	○	○	○	○	○
1.2 How the class topics, activities, reading and assignments fit together	○	○	○	○	○	○
1.3 The pace of the class	○	○	○	○	○	○
1.4 Please comment on how the INSTRUCTIONAL APPROACH to this class helped your learning.						
1.5 How has this class CHANGED THE WAYS YOU LEARN/STUDY?						

Class Activities

2. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
2.1 Attending lectures						
2.2 Participating in discussions during class						
2.3 Listening to discussions during class						
2.4 Participating in group work during class						
2.5 Doing hands-on classroom activities						
2.6 Specific Class Activities	no help	a little help	moderate help	much help	great help	not applicable
2.6.1 Class Activity 1 [Fill in]						
2.6.2 Class Activity 2 [Fill in]						
2.6.3 Class Activity 3 [Fill in]						

2.7 Please comment on how the CLASS ACTIVITIES helped your learning.

2.8 Please comment on HOW OFTEN YOU PARTICIPATED in class discussions and HOW THE ATMOSPHERE IN THE CLASSROOM ENCOURAGED OR DISCOURAGED your participation.

Assignments, graded activities and tests

3. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
3.1 Graded assignments (overall) in this class						
3.2 Writing assignments (overall)	no help	a little help	moderate help	much help	great help	not applicable
3.2.1 Writing assignment 1 [Fill in]						
3.2.2 Writing assignment 2 [Fill in]						
3.2.3 Writing assignment 3 [Fill in]						
3.3 Other graded assignments	no help	a little help	moderate help	much help	great help	not applicable
3.3.1 Assignment 1 [Fill in]						
3.3.2 Assignment 2 [Fill in]						
3.3.3 Assignment 3 [Fill in]						
3.4 Graded group projects						
3.5 Opportunities for in-class review (given by the instructor or TA)						
3.6 The number and spacing of tests						
3.7 The fit between class content and tests						
3.8 The mental stretch required by tests						
3.9 The way the grading system helped me understand what I needed to work on						
3.10 The feedback on my work received after tests or assignments						

3.11 Please comment on how the GRADED ACTIVITIES AND TESTS helped your learning.

Class Resources

4. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
4.1 The primary textbook	○	○	○	○	○	○
4.2 Other reading materials	no help	a little help	moderate help	much help	great help	not applicable
4.2.1 Reading material 1 [Fill in]	○	○	○	○	○	○
4.2.2 Reading material 2 [Fill in]	○	○	○	○	○	○
4.2.3 Reading material 3 [Fill in]	○	○	○	○	○	○
4.3 Online materials (other than teacher-provided online notes or presentations)	○	○	○	○	○	○
4.4 Online notes or presentations posted by instructor	○	○	○	○	○	○
4.5 Visual resources used in class (i.e. PowerPoint, slides, models, demonstrations)	○	○	○	○	○	○
4.6 Please comment on how the RESOURCES in this class helped your learning.						

The information you were given

5. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
5.1 Explanation of how the class activities, reading and assignments related to each other	○	○	○	○	○	○
5.2 Explanation given by instructor of how to learn or study the materials	○	○	○	○	○	○
5.3 Explanation of why the class focused on the topics presented	○	○	○	○	○	○
5.4 Please comment on HOW the INFORMATION YOU RECEIVED about the class helped your learning.						

Support for you as an individual learner

6. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	no help	a little help	moderate help	much help	great help	not applicable
6.1 Interacting with the instructor during class	○	○	○	○	○	○
6.2 Interacting with the instructor during office hours	○	○	○	○	○	○
6.3 Working with teaching assistants during class	○	○	○	○	○	○
6.4 Working with teaching assistants outside of class	○	○	○	○	○	○
6.5 Working with peers during class	○	○	○	○	○	○
6.6 Working with peers outside of class	○	○	○	○	○	○
6.7 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class.						

Your understanding of class content

7. As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
7.1 The main concepts explored in this class	○	○	○	○	○	○
7.2 The relationships between the main concepts	○	○	○	○	○	○
7.3 The following concepts that have been explored in this class	no gains	a little gain	moderate gain	good gain	great gain	not applicable
7.3.1 (Concept 1) [Fill in]	○	○	○	○	○	○
7.3.2 (Concept 2) [Fill in]	○	○	○	○	○	○
7.3.3 (Concept 3) [Fill in]	○	○	○	○	○	○
7.4 How ideas from this class relate to ideas encountered in other classes within this subject area	○	○	○	○	○	○
7.5 How ideas from this class relate to ideas encountered in classes outside of this subject area	○	○	○	○	○	○
7.6 How studying this subject area helps people address real world issues	○	○	○	○	○	○

7.7 Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class.

7.8 Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas.

Increases in your skills

8. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
8.1 Finding articles relevant to a particular problem in professional journals or elsewhere	○	○	○	○	○	○
8.2 Critically reading articles about issues raised in class	○	○	○	○	○	○
8.3 Identifying patterns in data	○	○	○	○	○	○
8.4 Recognizing a sound argument and appropriate use of evidence	○	○	○	○	○	○
8.5 Developing a logical argument	○	○	○	○	○	○
8.6 Writing documents in discipline-appropriate style and format	○	○	○	○	○	○
8.7 Working effectively with others	○	○	○	○	○	○
8.8 Preparing and giving oral presentations	○	○	○	○	○	○

8.9 Please comment on what SKILLS you have gained as a result of this class.

Class impact on your attitudes

9. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
9.1 Enthusiasm for the subject	○	○	○	○	○	○
9.2 Interest in discussing the subject area with friends or family	○	○	○	○	○	○
9.3 Interest in taking or planning to take additional classes in this subject	○	○	○	○	○	○
9.4 Confidence that you understand the material	○	○	○	○	○	○
9.5 Confidence that you can do this subject area	○	○	○	○	○	○
9.6 Your comfort level in working with complex ideas	○	○	○	○	○	○
9.7 Willingness to seek help from others (teacher, peers, TA) when working on academic problems	○	○	○	○	○	○

9.8 Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.

Integration of your learning

10. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?	no gains	a little gain	moderate gain	good gain	great gain	not applicable
10.1 Connecting key class ideas with other knowledge	○	○	○	○	○	○
10.2 Applying what I learned in this class in other situations	○	○	○	○	○	○
10.3 Using systematic reasoning in my approach to problems	○	○	○	○	○	○
10.4 Using a critical approach to analyzing data and arguments in my daily life	○	○	○	○	○	○

10.5 What will you CARRY WITH YOU into other classes or other aspects of your life?

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Appendix 6: SALG 2.0 Baseline Instrument

PREVIEW INSTRUMENT #9863

Sign out

This page allows to you to preview an instrument. From this page, you can make a copy the entire instrument without changes, copy questions from the instrument, or make a copy of the instrument with changes.

My personal page
Reuse this instrument
Copy questions from this instrument
Edit this instrument

- **Status: Editing** [?]
- Instructor: Stephen Carroll
- Institution: Santa Clara University
- Department: English
- Course:
- Semester:
- Description:
- Survey start date: (not set)
- Survey end date: (not set)
- Visibility: Default [?]

Instructions to students:

Teachers value students' feedback and take it into account when improving their courses. Please be as precise as you can in your answers. Please choose "not applicable" for any activity you did not do. You may find one or more questions at the end of each section that invite an answer in your own words. Please comment candidly, bearing in mind that future students will benefit from your thoughtfulness. Remember that this is an anonymous survey: your teacher will never know what any individual student has written.

You may see the following note next to some questions:

"***D***" — Department question. The department head can view the responses to these questions.

Understanding

1. Presently, I understand...

1.1 The following concepts that will be explored in this class	not applicable	not at all	just a little	somewhat	a lot	a great deal
1.1.1 (Concept 1) [Fill in]	○	○	○	○	○	○
1.1.2 (Concept 2) [Fill in]	○	○	○	○	○	○
1.1.3 (Concept 3) [Fill in]	○	○	○	○	○	○
1.2 The relationships between those main concepts	○	○	○	○	○	○
1.3 How ideas we will explore in this class relate to ideas I have encountered in other classes within this subject area	○	○	○	○	○	○
1.4 How ideas we will explore in this class relate to ideas I have encountered in classes outside of this subject area	○	○	○	○	○	○
1.5 How studying this subject helps people address real world issues	○	○	○	○	○	○

1.6 What do you expect to understand at the end of the class that you do not know now?

Skills

2. Presently, I can...	not applicable	not at all	just a little	somewhat	a lot	a great deal
2.1 Find articles relevant to a particular problem in professional journals or elsewhere						
2.2 Critically read articles about issues raised in class						
2.3 Identify patterns in data						
2.4 Recognize a sound argument and appropriate use of evidence						
2.5 Develop a logical argument						
2.6 Write documents in discipline-appropriate style and format						
2.7 Work effectively with others						
2.8 Prepare and give oral presentations						
2.9 What do you expect to be able to do at the end of the course that you cannot do now?						

Attitudes

3. Presently, I am...	not applicable	not at all	just a little	somewhat	a lot	a great deal
3.1 Enthusiastic about the subject						
3.2 Interested in discussing the subject area with friends or family						
3.3 Interested in taking or planning to take additional classes in this subject						
3.4 Confident that I understand the subject						
3.5 Confident that I can do this subject						
3.6 Comfortable working with complex ideas						
3.7 Willing to seek help from others (teacher, peers, TA) when working on academic problems						
3.8 Please comment on your present level of interest in this subject.						

Integration of learning

4. Presently, I am in the habit of...	not applicable	not at all	just a little	somewhat	a lot	a great deal
4.1 Connecting key ideas I learn in my classes with other knowledge						
4.2 Applying what I learn in classes to other situations						
4.3 Using systematic reasoning in my approach to problems						
4.4 Using a critical approach to analyzing data and arguments in my daily life						
4.5 Please comment on how you expect this material to integrate with your studies, career, and/or life?						

Major

5. What best characterizes your major in college?	Yes	No
5.1 Major in this subject area	○	○
5.2 Not a major in this subject area	○	○
5.3 Undecided at this time	○	○
5.4 Plan on becoming a major in this subject area	○	○
5.5 Plan on becoming a major in another area	○	○

GPA

6. What is your current GPA in a system that assumes a 4.00 as an A (highest score possible)?	4.00-3.60	3.01-3.59	2.51-3.00	2.01-2.50	2.00 or lower
6.1 My GPA is...	○	○	○	○	○

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Appendix 7: SALG 2.0 Analysis Page

INSTRUMENT ANALYSIS

Sign out

My personal page
Instrument dashboard

On this page, you can view and download a summary of results from one or more SALG instruments. You can also view results across instruments.

Results displayed for the following instrument:

ID	Open Close	Instructor	Course	Semester	Description	N	
377	Tue Jun 05, 2007 Fri Jun 15, 2007	Stephen Carroll	English 190	Spring 2007	Practicum in Ethics of Biotechnology	6	download

If you'd like to aggregate data across instruments, you can add another instrument to this analysis.

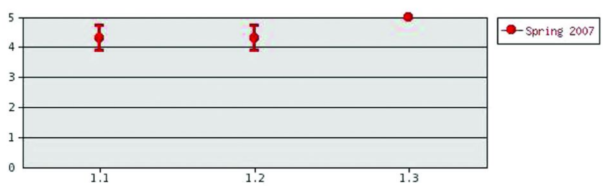
Cross-tabulate questions ?

Frequency distributions of scale results
The table below lists the percentage of students responding in each category, along with the mean and number of responses for that item. If you'd like an more detailed analysis, click on the 'details' link to the right of that item.

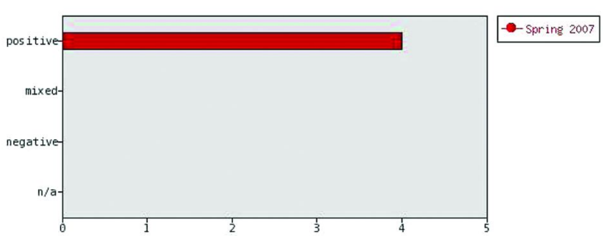
The Class Overall

1. HOW MUCH did the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
1.1 The instructional approach taken in this class	0%	0%	0%	67%	33%	0%	4.3	6	details
1.2 The pace of the class	0%	0%	0%	67%	33%	0%	4.3	6	details
1.3 Using Angel to turn in papers and receive feedback	0%	0%	0%	0%	100%	0%	5.0	6	details
1.4 Please comment on how the INSTRUCTIONAL APPROACH to this class helped your learning.	Enter codes for text answers						--	5	details
1.5 How has this class CHANGED THE WAYS YOU LEARN/STUDY?	+note 67%						--	6	details

Summary of scale results
The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.



Summary of text results
Below is a summary of the postive/negative/mixed codes assigned for the open-ended items.

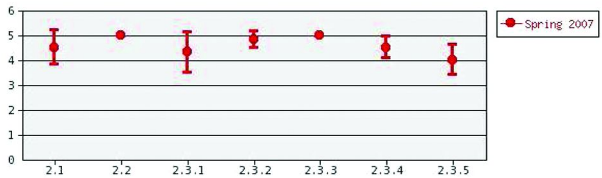


Class Activities

2. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
2.1 Talking in class about how to learn, how to read and study, and how to write	0%	0%	17%	17%	67%	0%	4.5	6	details
2.2 Participating in discussions during class	0%	0%	0%	0%	100%	0%	5.0	6	details
2.3 Specific Class Activities	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
2.3.1 Going over papers together in class	0%	0%	33%	0%	67%	0%	4.3	6	details
2.3.2 Going over thesis statements in class	0%	0%	0%	17%	83%	0%	4.8	6	details
2.3.3 Analyzing ethical arguments in class	0%	0%	0%	0%	100%	0%	5.0	6	details
2.3.4 Working on the posters in class	0%	0%	0%	50%	50%	0%	4.5	6	details
2.3.5 Writing analyses of the weekly readings	0%	0%	17%	50%	17%	17%	4.0	5	details
2.4 Please comment on how the CLASS ACTIVITIES helped your learning.	Enter codes for text answers						--	5	details
2.5 Please comment on HOW OFTEN YOU PARTICIPATED in class discussions and HOW THE ATMOSPHERE IN THE CLASSROOM ENCOURAGED OR DISCOURAGED your participation.	Enter codes for text answers						--	6	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.



Assignments, graded activities and tests

3. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?							Mean	N	
3.1 Writing assignments (overall)	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
3.1.1 Writing 2 drafts before the final paper was due	0%	0%	0%	0%	100%	0%	5.0	6	details
3.1.2 Writing the problem for your poster (first paper)	0%	0%	0%	0%	100%	0%	5.0	6	details
3.1.3 The BT corn case	0%	17%	67%	17%	0%	0%	3.0	6	details
3.2 The thesis statement for your poster	0%	0%	0%	17%	83%	0%	4.8	6	details
3.3 Opportunities for in-class review	0%	0%	17%	33%	50%	0%	4.3	6	details
3.4 The feedback on my work received after assignments	0%	0%	0%	0%	100%	0%	5.0	6	details
3.5 Please comment on how the GRADED ACTIVITIES helped your learning.	Enter codes for text answers						--	6	details

Summary of scale results

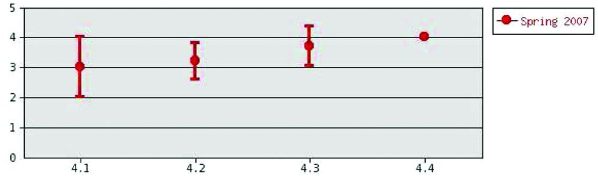
The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

Class Resources

4. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
4.1 The Aims of Argument	0%	50%	17%	17%	17%	0%	3.0	6	details
4.2 Style	0%	17%	50%	33%	0%	0%	3.2	6	details
4.3 Miscellaneous online materials	0%	0%	50%	33%	17%	0%	3.7	6	details
4.4 Reading peers' papers on Angel	0%	0%	0%	100%	0%	0%	4.0	6	details
4.5 Please comment on how the RESOURCES in this class helped your learning.	Enter codes for text answers						--	6	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

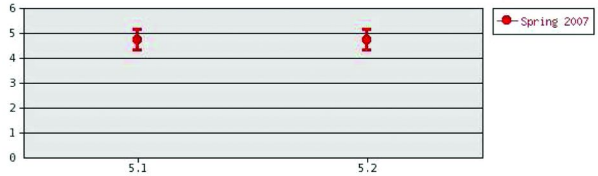


The information you were given

5. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
5.1 Explanation of how the class activities and assignments related to each other and to Bio 171	0%	0%	0%	33%	67%	0%	4.7	6	details
5.2 Explanation given by instructor of how to learn and how to study the materials	0%	0%	0%	33%	67%	0%	4.7	6	details
5.3 Please comment on HOW the INFORMATION YOU RECEIVED about how to work in this class helped your learning.	Enter codes for text answers						--	6	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

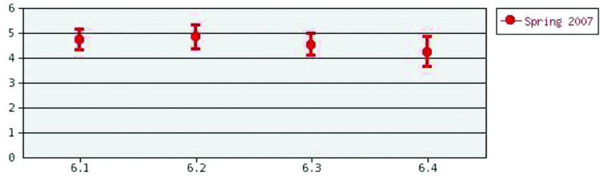


Support for you as an individual learner

6. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?	1:no help	2:a little help	3:moderate help	4:much help	5:great help	9:not applicable	Mean	N	
6.1 Interacting with the instructor during class	0%	0%	0%	33%	67%	0%	4.7	6	details
6.2 Interacting with the instructor during office hours	0%	0%	0%	17%	50%	33%	4.8	4	details
6.3 Working with peers during class	0%	0%	0%	50%	50%	0%	4.5	6	details
6.4 Working with peers outside of class	0%	0%	17%	50%	33%	0%	4.2	6	details
6.5 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class.	Enter codes for text answers						--	6	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

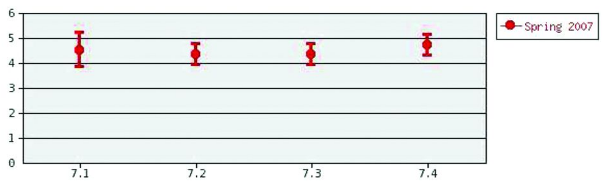


Your understanding of class content

7. As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N	
7.1 The main scientific and ethical concepts explored in this class	0%	0%	17%	17%	67%	0%	4.5	6	details
7.2 The relationships between the main concepts	0%	0%	0%	67%	33%	0%	4.3	6	details
7.3 How ideas from this class relate to ideas enountered in other classes.	0%	0%	0%	67%	33%	0%	4.3	6	details
7.4 How studying this subject area helps people address real world issues	0%	0%	0%	33%	67%	0%	4.7	6	details
7.5 Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class.	Enter codes for text answers						--	6	details
7.6 Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER and USE key ideas.	Enter codes for text answers						--	6	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

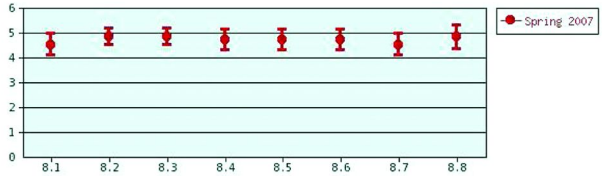


Increases in your skills

8. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N	
8.1 Thinking critically about your own ideas	0%	0%	0%	50%	50%	0%	4.5	6	details
8.2 Using writing to develop your own thinking about an issue.	0%	0%	0%	17%	83%	0%	4.8	6	details
8.3 Thinking critically about how to communicate your ideas.	0%	0%	0%	17%	83%	0%	4.8	6	details
8.4 Recognizing a sound argument and appropriate use of evidence	0%	0%	0%	33%	67%	0%	4.7	6	details
8.5 Developing a logical argument	0%	0%	0%	33%	67%	0%	4.7	6	details
8.6 Writing documents in discipline-appropriate style and format	0%	0%	0%	33%	67%	0%	4.7	6	details
8.7 Working effectively with others	0%	0%	0%	50%	50%	0%	4.5	6	details
8.8 Preparing and giving oral presentations	0%	0%	0%	17%	50%	33%	4.8	4	details
8.9 Please comment on what SKILLS you have gained as a result of this class.	Enter codes for text answers						--	5	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

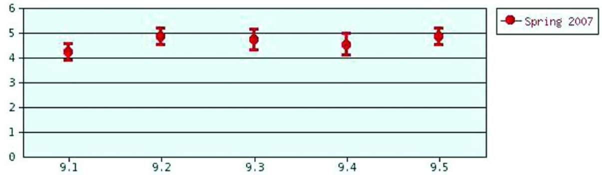


Class impact on your attitudes

9. As a result of your work in this class, what GAINS DID YOU MAKE in the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N	
9.1 Enthusiasm for the subject	0%	0%	0%	83%	17%	0%	4.2	6	details
9.2 Confidence that you understand the material	0%	0%	0%	17%	83%	0%	4.8	6	details
9.3 Confidence that you can do this kind of thinking and writing	0%	0%	0%	33%	67%	0%	4.7	6	details
9.4 Your comfort level in working with complex ideas	0%	0%	0%	50%	50%	0%	4.5	6	details
9.5 Willingness to seek help from others (teacher, peers, TA) when working on academic problems	0%	0%	0%	17%	83%	0%	4.8	6	details
9.6 Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.	Enter codes for text answers						--	5	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.

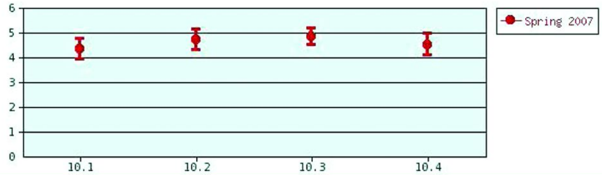


Integration of your learning

10. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following?	1:no gains	2:a little gain	3:moderate gain	4:good gain	5:great gain	9:not applicable	Mean	N	
10.1 Connecting ideas about writing with other knowledge	0%	0%	0%	67%	33%	0%	4.3	6	details
10.2 Applying what I learned about thinking and writing in this class in other situations	0%	0%	0%	33%	67%	0%	4.7	6	details
10.3 Using systematic reasoning in my approach to problems	0%	0%	0%	17%	83%	0%	4.8	6	details
10.4 Using a critical approach to analyzing data and arguments in my daily life	0%	0%	0%	50%	50%	0%	4.5	6	details
10.5 What will you CARRY WITH YOU into other classes or other aspects of your life?	Enter codes for text answers						--	4	details

Summary of scale results

The graphic below lists the mean and confidence interval (±3 times the standard error) for each item.



How to improve the class for next time

		Mean	N	
11. If we were to offer this class again, what changes should we make?				
11.1 What should we spend more time on?	Enter codes for text answers	--	6	details
11.2 What should we spend less time on?	Enter codes for text answers	--	4	details
11.3 If there is anything else you want me to know about the class, please add it here.	Enter codes for text answers	--	6	details

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Appendix 8: SALG 2.0 Scale-Question Detail

English Text: a A

QUESTION DETAIL

Sign out

My personal page
Back to instrument analysis

Results displayed for the following instrument:

ID	Open Close	Instructor	Course	Semester	Description	N
377	Tue Jun 05, 2007 Fri Jun 15, 2007	Stephen Carroll	English 190	Spring 2007	Practicum in Ethics of Biotechnology	6

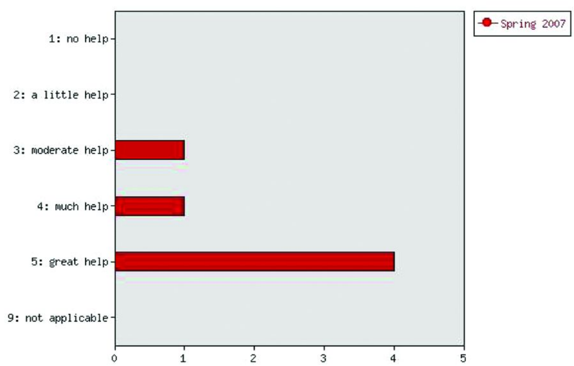
Results for Question: Talking in class about how to learn, how to read and study, and how to write

Distribution of responses
The distribution of responses to this questions appears below.

Choice	Responses	Individual Results
1: no help	0/7 (0%)	
2: a little help	0/7 (0%)	
3: moderate help	1/7 (14%)	95747
4: much help	1/7 (14%)	36787
5: great help	4/7 (57%)	18236 39673 75797 97504
9: not applicable	0/7 (0%)	

Statistics
Descriptive statistics for this item appear below.

- N: 6
- Mean: 4.5
- Std dev: 0.84
- Mode: "5: great help"
- Number of answers at the mode: 4



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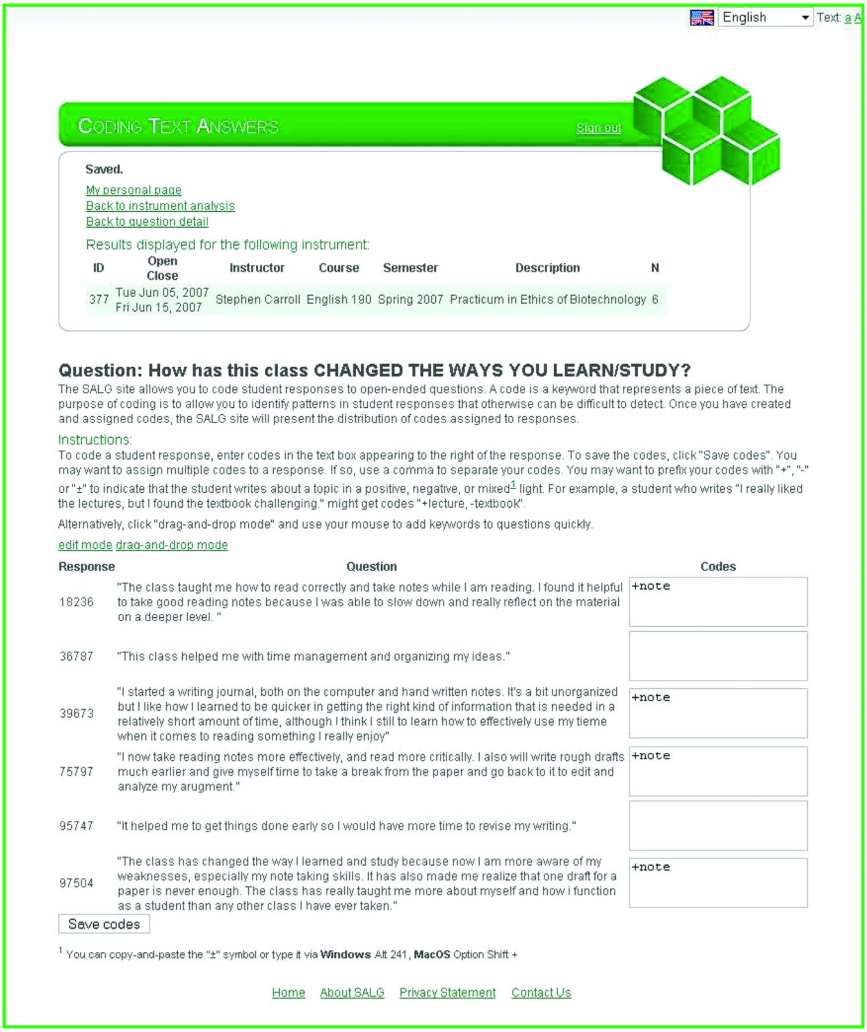
Appendix 9: SALG 2.0 Open-Ended Question Detail



English Text: a A

CODING TEXT ANSWERS Sign out

Saved.

My personal page
Back to instrument analysis
Back to question detail

Results displayed for the following instrument:

ID	Open Close	Instructor	Course	Semester	Description	N
377	Tue Jun 05, 2007 Fri Jun 15, 2007	Stephen Carroll	English 190	Spring 2007	Practicum in Ethics of Biotechnology	6

Question: How has this class CHANGED THE WAYS YOU LEARN/STUDY?

The SALG site allows you to code student responses to open-ended questions. A code is a keyword that represents a piece of text. The purpose of coding is to allow you to identify patterns in student responses that otherwise can be difficult to detect. Once you have created and assigned codes, the SALG site will present the distribution of codes assigned to responses.

Instructions:

To code a student response, enter codes in the text box appearing to the right of the response. To save the codes, click "Save codes". You may want to assign multiple codes to a response. If so, use a comma to separate your codes. You may want to prefix your codes with "+", "-" or "±" to indicate that the student writes about a topic in a positive, negative, or mixed[1] light. For example, a student who writes "I really liked the lectures, but I found the textbook challenging." might get codes "+lecture, -textbook".

Alternatively, click "drag-and-drop mode" and use your mouse to add keywords to questions quickly.

edit mode drag-and-drop mode

Response	Question	Codes
18236	"The class taught me how to read correctly and take notes while I am reading. I found it helpful to take good reading notes because I was able to slow down and really reflect on the material on a deeper level. "	+note
36787	"This class helped me with time management and organizing my ideas."	
39673	"I started a writing journal, both on the computer and hand written notes. It's a bit unorganized but I like how I learned to be quicker in getting the right kind of information that is needed in a relatively short amount of time, although I think I still to learn how to effectively use my tieme when it comes to reading something I really enjoy"	+note
75797	"I now take reading notes more effectively, and read more critically. I also will write rough drafts much earlier and give myself time to take a break from the paper and go back to it to edit and analyze my arugment."	+note
95747	"It helped me to get things done early so I would have more time to revise my writing."	
97504	"The class has changed the way I learned and study because now I am more aware of my weaknesses, especially my note taking skills. It has also made me realize that one draft for a paper is never enough. The class has really taught me more about myself and how i function as a student than any other class I have ever taken."	+note

Save codes

[1] You can copy-and-paste the "±" symbol or type it via **Windows** Alt 241, **MacOS** Option Shift +

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