

Chemistry, Society, and Civic Engagement (Part 1): The SENCER Project

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At the 2002 Science Education for New Civic Engagements and Responsibilities (SENCER) Summer Institute, Alan Leshner of the American Association for the Advancement of Science asserted: “Science is always ultimately about people and life” (1). We agree, as most likely did the others assembled at the Institute. And if indeed science ultimately connects people and the world in which they live, certain intellectual tasks lie before us as chemical educators. This paper describes the interdisciplinary work of a group of people committed both to better defining and to accomplishing these tasks.

As a change agent, SENCER is concerned with institutional and curricular reform, particularly in regards to designing new science courses and rethinking older ones in ways that make the connections between science, people, and society more transparent. Through such connections, these courses invite students (as well as their instructors) to engage in the complex social issues that face us today locally, regionally, and globally. Ultimately, as Leshner pointed out, *science is about people and life*. So is the SENCER project.

We first describe how the SENCER approach contributes to the undergraduate chemistry curriculum. Next we offer examples of chemistry courses that have been constructed on the SENCER model. And finally, we acknowledge the challenges that underlie the project, including designing the SENCER course, setting and assessing its goals, and teaching for civic engagement.

The SENCER Project

In 2005, SENCER entered its fifth year as a national dissemination project. Originally affiliated with the Association of American Colleges and Universities, SENCER now has its home in the National Center for Science and Civic Engagement at the Harrisburg University of Science and Technology. One of the authors of this paper (KKO) is the co-founder of the Center, and a cadre of SENCER senior associates (including the other authors of this paper) serves as the faculty for the SENCER Summer Institutes for curricular development. Over 300 participants attended the 2005

Institute, representing 106 institutions, 30 states, and three continents. In addition, the senior associates contribute background papers and descriptions of model courses, as do the SENCER participants themselves. The details, as well as a quarterly newsletter, can be found on the SENCER Web site (2). Symposia featuring SENCER courses have been organized at recent national meetings (3–5).

At the heart of the SENCER project lie its undergraduate courses for nonscience majors, including courses currently being taught and courses under development by teams at over 150 colleges and universities. These courses explicitly teach *through* complex, current, and contested real-world issues *to* basic scientific principles, thus engaging the learners in the complexities of both. In fact, the previous sentence is foremost among the ideals (List 1) to which the SENCER courses

List 1. The Ideals of the SENCER Project

- Robustly connecting science and civic engagement by teaching *through* complex, contested, current, and unresolved public issues *to* basic science
- Inviting students to put scientific knowledge and scientific method to immediate use on matters of immediate interest to students
- Helping reveal the limits of science by identifying elements of public issues where science doesn't help us decide what to do
- Showing 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, thus illuminating those elements with that knowledge
- Conceiving 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
- Seeking to extract from the immediate issues the larger, common lessons about scientific processes and methods
- Locating the responsibility of discovery—both the burdens and the pleasures—as the work of the student

ascribe. While the majority of SENCER courses—including those described in this paper—are designed for nonmajors, the SENCER principles are also being extended to courses within science majors.

Since the origin of the project, over 200 new or SENCER-modified courses have been developed, with many more in the planning stage.¹ As shown in Table 1, 23 courses have been published as SENCER models. Eliza Jane Reilly, editor of the model series, emphasizes that these models are *not* offered “as cookbooks or recipes to be copied and implemented as is” (6). Rather, the courses were chosen as models

because each successfully built on an intriguing topic and used this topic as a pathway to learning science. All have potential for broader implementation and adaptation.

Complex, real-world issues transcend disciplinary boundaries. For example, June Osborn, chair of the first National Commission on AIDS, coined the term “multidisciplinary trouble” to denote the complexities of HIV disease. HIV/AIDS is complex not only in terms of its blood and cell chemistry, but also with its social, political, and cultural complexities (7). The multidisciplinary aspects of HIV disease and its relationship to decision making and human behavior are mod-

Table 1. Distribution of National SENCER Model Courses, 2001–2005

Course Title by Year	Institution	Developers
2001		
Biomedical Issues of HIV/AIDS	Rutgers University	Monica Devanas
Mysteries of Migration	George Mason University	Thomas Wood, Elizabeth Gunn
Chemistry and the Environment	Santa Clara University	Amy Shachter
Science, Society, and Global Catastrophes	University of Wisconsin–Marathon	Theo Koupelis
2002		
Energy and the Environment	New York University	Trace Jordan
Geology and Development of Modern Africa	Hamilton College	Barbara Tewksbury
Human Genetics	Kent State University	Kim Fine
Tuberculosis	Franklin and Marshall College	Richard Fluck
2003		
Brownfield Action	Barnard College	Peter Bower
Chance	Spelman College	Nagambal Shah
Environment and Disease	Bard College	Michael Tibbetts, et al.
Global Warming	Evergreen State College	Sharon Anthony
Nutrition and Wellness	Drake University	LaRhee Henderson, Charisse Busing, et al.
2004		
Chemistry and Ethnicity: Uranium and American Indians	University of Wisconsin–Madison	Cathy Middlecamp, Omie Baldwin
Chemistry and Policy: A Course Intersection	Vassar College	Pinar Batur, Christopher Smart, Stuart Belli
Coal in the Heart of Appalachian Life	Fairmont State University	Philip Mason, et al.
Forensic Investigation: Seeking Justice through Science	Southern Oregon University	Gregory Miller
The Mathematics of Communication: Keeping Secrets	Rutgers University	Stephen Greenfield
Sustainability and Human Health: A Learning Community	Wagner College	Donald Stearns, Kim Worthy
2005		
Chemistry of Daily Life: Malnutrition and Diabetes	Saint Vincent College	Matthew Fisher
Nanotechnology: Context and Content	Rice University	Kristen Kublinowski, Christopher Kelty
Renewable Environment: Transforming Urban Neighborhoods	St. Mary's College, California	Steven Bachofer, Phylis Cancelli Martinelli
Riverscape	Hampton University	Anne L. Pierce, George Burbank, Barbara Abraham, Judith Davis

eled in the SENCER course entitled Biomedical Issues of HIV/AIDS (8). The term “multidisciplinary trouble” now has come to represent many of the SENCER approaches and models. Predisciplinary, however, might be a better word choice (9). Although students may enter our science courses with well-formed career goals, these students are predisciplinary in the sense that they barely have scratched the surface of even one discipline. How might we design a course with this predisciplinary condition in mind? In the simplest terms possible (and following the ideals in List 1), we would start where students’ interests lie and use these interests as an organizing principle—a backbone on which the remaining information can be attached and structured.

SENCER builds upon earlier educational initiatives that explored the intersection of science and society. For example, *Chemistry in Context (CiC)*, a project of the American Chemical Society, approached the curriculum for nonscience majors in a similar manner over 15 years ago (10, 11). Now in its fifth edition, the *CiC* textbook continues to engage students in real-world issues that link chemical principles with personal, societal, and global concerns. Accordingly, the SENCER principal investigators selected the *CiC* textbook as one of several models on which to base their project. In fact, the developers of an early SENCER model course, Energy and the Environment (see below) selected and continue to use *CiC* as the course textbook (12).

More recently, other papers have appeared in this *Journal* that describe how instructors have related chemistry to issues of public policy. For example, Kimbrough et al., who teach science and public policy through role playing, point out that “We, as educators, need to impart to our students an understanding of the challenges one encounters at the technology–society interface” (13). Similarly, in constructing a course for nonscience majors, Trumbore and his co-workers pose the question: “What are some of the subjects that vitally concern students, and in what ways is it possible to utilize these as vehicles in the teaching of chemistry?” His answer, *Chemistry and the Human Environment*, is a course that interfaces with the “physical, medical, philosophical, political, and economic environments” of students (14).

What is different about SENCER, as we shall describe, is the degree to which it articulates a general philosophy of curricular change linked to civic engagement and issues of public policy and how it assesses the impact on student learning. For example, consider two representations, admittedly simplified, of the approach that *Chemistry in Context* takes (Figure 1). Figure 1A represents teaching *through* the topic of global climate change *to* underlying scientific principles such as fossil fuel combustion and the greenhouse effect (Chapter Three, “The Chemistry of Global Warming”). Similarly, Figure 1B represents teaching *through* the topic of nuclear energy *to* topics such as atomic structure and radioactive decay (Chapter Seven, “The Fires of Nuclear Fission”). Instructors using *CiC* typically select six or more chapters to construct a course that fits their institutional needs and those of their students.²

In contrast, either a single topic or a set of closely linked topics is more typical of a SENCER course, as evidenced by the titles in Table 1. For example, the courses Tuberculosis, Coal in the Heart of Appalachian Life, Mysteries of Migration, and Global Warming are all structured around a single

complex issue. Although Science, Society, and Global Catastrophes includes several topics (global warming, ozone depletion, plagues, extinctions, and nuclear winter), these topics are linked through the common theme of catastrophes that have affected our planet in the past or may do so in the future. Thus, by virtue of pursuing a single topic or set of topics, SENCER courses can more deeply or directly connect to a particular set of social issues. Figure 2 shows the directness of this connection for the 2004 model SENCER course, *Uranium and American Indians* (15). The content rings extend out to intersect with a community of people, the Diné, who suffered lung cancer and contamination of their lands in the Four Corners Area³ as a result of uranium mining in

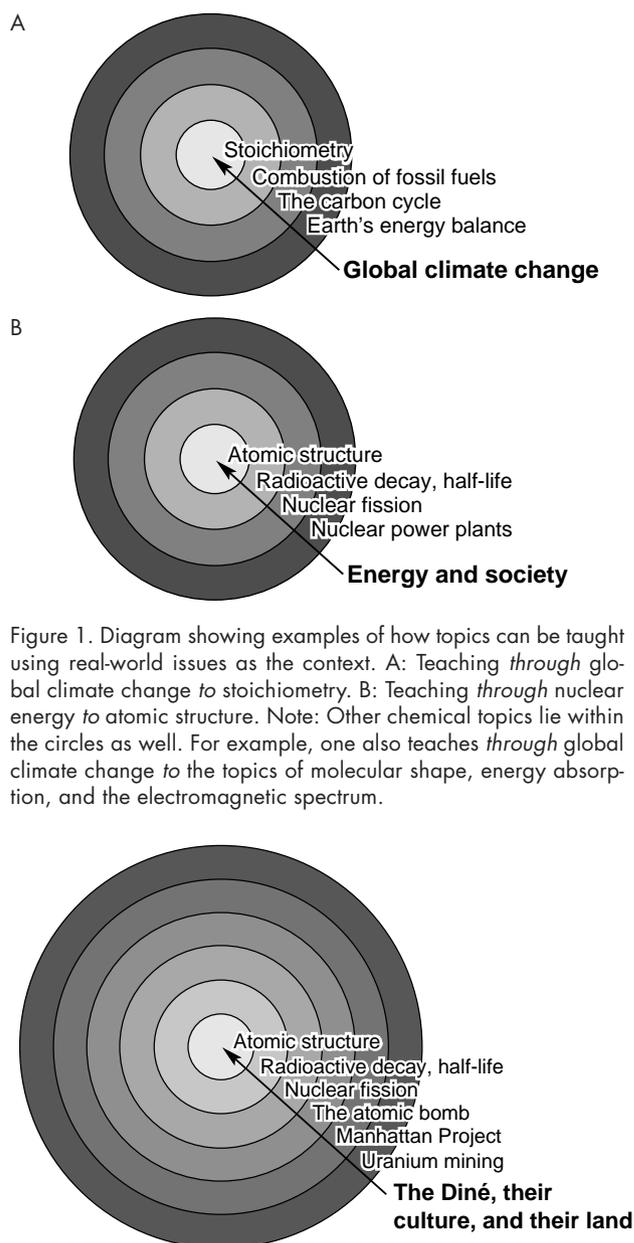


Figure 1. Diagram showing examples of how topics can be taught using real-world issues as the context. A: Teaching *through* global climate change *to* stoichiometry. B: Teaching *through* nuclear energy *to* atomic structure. Note: Other chemical topics lie within the circles as well. For example, one also teaches *through* global climate change *to* the topics of molecular shape, energy absorption, and the electromagnetic spectrum.

Figure 2. Diagram representing the teaching approach for the course *Uranium and American Indians*, which is taught *through* the context of the Diné, their culture, and their land *to* the underlying scientific topics.

the 1950s. Uranium and American Indians engages students in both the complexities of chemistry and those of culture, as described by the second paper in this series (16).

Thus, we believe SENCER to be a timely and a compelling project, one that strongly asserts that *science can and should engage today's students*. Like the projects that preceded it, SENCER is not about learning simple scientific topics in simple ways. Rather, it is about engaging in challenging and complex issues that are important to a wide range of people and then learning about these issues in multiple, appropriate ways. SENCER comes at a time in which the public is debating hotly contested issues such as stem cell research and global climate change. Issues such as these have caught the interest of people in communities everywhere and rely on science in general and chemistry in particular.

Examples of SENCER Chemistry Courses

As a central science, chemistry plays a central role in many SENCER courses. In this section, we highlight two SENCER model courses that involve chemistry: Energy and the Environment and Chemistry and the Environment.

Energy and the Environment

Like many SENCER courses, Energy and the Environment was developed as part of a broader undergraduate curriculum reform effort (17–18). In 1995, New York University's College of Arts and Science replaced its standard distribution requirement with a new general education curriculum called the Morse Academic Plan.⁴ This restructuring was motivated by the desire to provide undergraduate students majoring in the arts, humanities, and social sciences with an engaging and relevant experience of scientific inquiry. Energy and the Environment is one course option within the Morse Academic Plan and addresses complex environmental issues using the first eight chapters of *Chemistry in Context*. Students have the opportunity to perform experiments and interpret their own laboratory data (19). A core course objective is to assist students in becoming effective decision-makers in complex civic issues that involve science. This goal aligns with a recent report to the NSF on *Complex Environmental Systems* that recommends “enhancing public understanding of complex environmental information and decisions” (20).

For example, global climate change couples chemistry with fields such as economics, politics, domestic policy, and foreign affairs. In order to equip students to become civic participants, Energy and Environment first provides a scientific foundation. Topics include the role of solar radiation and Earth's atmosphere in creating a habitable climate, past climate change data from sources such as the Vostok ice core, and more recent evidence for warming trends. Students then explore the debates over whether global climate change is primarily anthropogenic in origin. The Kyoto Protocol is evaluated to see whether adoption of its proscriptions will mitigate CO₂ emissions. Finally, students use the 2001 National Research Council report on Climate Change Science (21) as the basis for a small-group discussion. This multi-week topic culminates with a short position paper on the scientific foundation of global warming. Through this approach, students appreciate that they can be active participants in addressing complex scientific issues with important civic dimensions (22).

Another topic explored in Energy and the Environment

is a precious resource that too often we take for granted—water. Students complete a water usage inventory and are often amazed to find that they exceed the national average of 100 gal per person, per day. Laboratory experiments include qualitative analysis of aqueous ions, measuring the hardness of water, and a titration to determine the acidity of rain. In some semesters these have been expanded into multi-week projects that allow students to work collaboratively on a question of local or national importance. For example, one group used a variety of water tests and purification methods to answer the question “Can we make Hudson River water safe to drink?” while another examined the effect of acid rain on plant growth.

Finally, Energy and the Environment is being used as the basis for the first service-learning experience to be offered within the general education curriculum. Beginning in spring 2005, students taking the lecture and laboratory course may also register for a linked service-learning seminar that involves partnering with a community garden and high school in Manhattan's Lower East Side. NYU students will work with 9th and 10th graders on educational projects that explore the science and policy aspects of urban environmental issues such as traffic and air pollution. In this capacity, they will be transformed into “teachers”. The benefits of this experience for both the students and the learning community were noted by a Kellogg Foundation report entitled Leadership Reconsidered: Engaging Higher Education in Social Change: “When students see themselves, or are viewed by others, as both learners and teachers, they take more responsibility for their own learning and help create more favorable learning environments for themselves and others” (23).

Chemistry and the Environment

Another early SENCER model course, Chemistry and the Environment, exemplifies the SENCER ideals through the use of campus- and community-based projects (24). Students propose projects relating to their community or to their daily lives with the goal of developing a set of policy recommendations. These projects, many of them based on a campus environmental resource assessment, helped students gain leadership skills and learn basic research methods, as described earlier in this *Journal* (25).

For example, students recently investigated making biodiesel fuel for use in a campus truck. The students prepared biodiesel fuel by a simple transesterification reaction, both from spent cooking oil (obtained from the campus cafeteria) and from new cooking oils. Their final recommendation was *not* to make the biodiesel on campus due to the difficulty in filtering the dirty oil. Rather, they proposed to seek an agreement with a local, large-scale biodiesel company to collect the cooking oil from campus and then sell its biodiesel back to the campus at a reduced price—a “closed loop” recommendation.

While learning the chemical principles that underlie issues, students also discuss the public policies relating to these issues. In the process, they obtain a basic familiarity with laws, regulations, and international agreements (the U.S. Clean Air Act, the U.S. Clean Water Act, the Montreal and Kyoto Protocols, and others) as well as a basic understanding of local, state, and federal regulatory agencies such as the Environmental Protection Agency, Food and Drug Administration, and Occupational Health and Safety Administration. Without

connecting the basic science to public policy, students would neither fully grasp the dimensions of these issues nor the opportunities for civic engagement, the topic of the next section.

The Challenges of Civic Engagement

In a modern democracy dependent on science and technology, we are challenged to offer citizens educational opportunities that prepare them to be informed, active, and engaged. A 2003 report on *The Civic Mission of Schools* from the Carnegie Corporation of New York and the Center for Information and Research on Civic Learning and Engagement (CIRCLE) comments “individuals do not automatically become free and responsible citizens but must be educated for citizenship” (26). The report continues that “the overall goal of civic education should be to help young people acquire and learn the skills, knowledge, and attitudes that will prepare them to be competent and responsible citizens throughout their lives”. National coalitions are also promoting civic engagement in higher education. For example, Campus Compact is a group of over 900 college and university presidents with a broad civic mission, including assisting faculty who seek to integrate community engagement into their teaching and research (27). Such national efforts underscore the importance and place of civic education in higher education.

The Obligations of Knowledge

More fundamentally, what do we mean by civic engagement? In its largest sense, the challenge of the SENCER project is to reveal the obligations of knowledge. More practically speaking, civic engagement challenges students to grapple with the question, “If you learn something, then in what ways might you be obliged to act?” In this sense, learning carries personal responsibilities.

As science educators, we need to consider various aspects of civic engagement in designing and teaching science courses. Civic engagement encompasses activities including memberships in groups or organizations, volunteering, and community problem solving; political activities such as voting and campaign participation; political voice including signing petitions, contacting officials, boycotting, and protesting (28).

Attentiveness and Intellectual Engagement

Civic engagement may also encompass an intellectual engagement with civic issues and attentiveness to civic events, such as regularly reading the newspaper and being willing to pay attention to the complexities of an unresolved issue. The importance of this seemingly simple example of civic engagement should not be underestimated and has been highlighted by David Burns as “knowledge to make our democracy” (29).

SENCER and Civic Engagement

SENCER courses are designed as both exercises in and catalysts of civic engagement. In a course organized around topics of civic importance, students naturally become more engaged either through increased awareness and attentiveness or by more participatory actions. Many SENCER courses involve contacting local officials or attending a local city council meeting to gain information as part of a course assignment. In the course *Chemistry and the Environment*, the participation of students, as members of the community, in basic community problem-solving through their research project is itself

civic engagement. More importantly, such participation fosters engagement beyond the course. Many students in *Chemistry and the Environment* continue their involvement to see their recommendations implemented.

Finally, as we mentioned earlier, the challenge of the SENCER project is to reveal the obligations of knowledge. By linking science and civic issues, students are more likely to see the responsibilities that come with such scientific knowledge. One of the exercises in *Chemistry and the Environment* is simply analyzing the annual water quality report distributed by the local water district. After the exercise, students have the ability to interpret the report—do they now have the responsibility of alerting the community if information in the report is of concern or incomplete? As students learn, their knowledge may compel new civic responsibilities and engagements.

The Challenges of Course Design

“Between the glimmer of an idea and the first day of classes there is an enormous gulf called the design process.” This warning was spoken by Barbara Tewksbury to those assembled at the 2004 Summer SENCER Institute (30). In describing the design process, she noted the challenge perceived by most instructors as foremost: how to be relevant, yet not to sacrifice content in the process.

Going beyond Content

We too acknowledge this challenge, recognizing the urge on the part of many instructors to “cover material”. However, SENCER courses are not about covering anything, *per se*. Realistically, the amount of content to master is impossibly large and, in and of itself, may be of low intrinsic value in that specific content items are not necessarily retained months and years later. Given this realization, two basic questions emerge. First, what goals can we articulate *beyond* content coverage? And second, what do the students in our classrooms today really need; more specifically, what should they be able to *do* after the course has ended? Thus, when designing a SENCER course, simply listing the content topics is *not* the sole or primary strategy to pursue.

Developing Skills and Abilities

SENCER courses typically include goals involving higher-order thinking skills. For example, the course goals of *Energy and the Environment*⁵ vary in complexity and include students’ learning to:

- Acquire a knowledge of foundational concepts, processes, and terminology in chemistry
- Develop skills in problem solving and use of quantitative reasoning
- Understand the methods of scientific investigation, including the roles of experiments and computer simulations
- Critically evaluate new advances in our understanding of environmental science as reported by news media
- Address the complex economic, political, and policy aspects of environmental issues

Implicit in this discussion is that a SENCER course can be designed in multiple ways to add value to the lives of those in the classroom. Of necessity, an instructor also will need to make choices based on the institutional context (e.g., course level, prerequisites), course structure (e.g., lab, class-

room size, and type), and the nature of the students taking the course (e.g., computer fluency, writing skills). Nonetheless, it is common to the design of all SENCER courses to articulate goals beyond covering content.

The Challenges of Assessment

Assessment Methods

An assessment instrument should closely parallel the goals that an instructor sets for students in a course. Accordingly, the assessment of student learning in SENCER courses varies by instructor because of differing course goals. Model course developers (Table 1) used a variety of methods to monitor their students' attainment of knowledge, skills, and attitudes. These included pre- and post-course surveys, conventional exams, narrative evaluations, assessments of course projects (including student self-assessment and peer assessment), case studies, debates, and even course alumni tracking.

To complement the assessment methods just mentioned, the SENCER project developed an assessment plan to provide information about the ways in which SENCER courses as a group were (or were not) successfully influencing student learning. Since no existing course assessment instrument matched the particular goals of SENCER courses, a new assessment instrument was developed modeled on the Student Assessment of Learning Gains, better known as "the SALG".

Assessment Instruments

The SALG instrument is an online course evaluation survey developed by Elaine Seymour through her work as an evaluator of the NSF-funded Chemistry Consortium (New Traditions, MC²). Questions on the SALG ask students to reflect and report on the aspects of a course that helped them to learn and the extent to which they have made gains in a course. The instrument can be customized to the goals and activities of any course and an instructor can implement it through the SALG Web site (31), which is free and available for use by instructors in any course in any discipline. While general enough to be used in any discipline, the basic structure of the SALG instrument is based upon the needs of chemistry instructors and students throughout the country involved in innovative introductory chemistry courses.

Table 2. Components of the SENCER SALG Instrument

Area	Stem Question	Sample Items
Confidence	After finishing this class I am <i>confident</i> that I can ...	Think critically about scientific findings I read in the media Make an argument using scientific evidence
Interest	After finishing this class I am <i>interested</i> in ...	Reading about science and its relation to civic issues Discussing science with friends or family
Engagement in Civic Activities	After finishing this class I am more <i>likely</i> to ...	Write a letter or email a public official about a science-related issue Debate or offer public comment on a civic or political issue

The SENCER SALG instrument is an adaptation of the SALG instrument intended for science courses that address real-life issues and involve students in a scientific investigation. The SENCER SALG has pre- and post-course forms, each with three major sections: confidence in science skills, interest in engaging in science-related activities, and engagement in civic activities. Students rate themselves in these areas on a five-point scale. In addition, the post-course form includes items that ask students to rate the extent to which elements of the course helped them learn. The purpose of the SENCER SALG is to assist instructors in observing changes in students' confidence, interest, and in self-reported behavior as a result of their course. Example questions are shown in Table 2.

The first version of the SENCER SALG was piloted in fall 2003. Major revisions were made after the pilot, and the revised instrument was implemented via the SALG Web site in fall 2003 and summer 2004. During this period, the SENCER SALG was used by 24 instructors in 32 courses and completed by 1374 students. Of these courses, 23 were SENCER courses; 9 of the courses were not but were often taught by SENCER Summer Institute participants.

Assessment Results

Briefly, the evaluation of the SENCER SALG assessment data has found the following results (32).

Demographics

The majority of SENCER students are female, non-science majors, and have taken few science courses.

Confidence

SENCER students have higher gains than non-SENCER students regarding their confidence in discussing scientific concepts with friends and family, thinking critically about scientific readings in the media, determining what is and isn't valid scientific evidence in the media, making an argument using scientific evidence, and determining the difference between science and pseudo-science. SENCER students had smaller gains in one area—giving a class presentation about a science topic.

Interest

SENCER students had higher gains than non-SENCER students with respect to their interest in all items. These gains included discussing science with family or friends, reading articles about science in magazines, journals, and on the Internet, and taking additional science courses.

Engagement in Civic Activities

SENCER students reported being more likely to engage in the following civic activities than non-SENCER students: writing a letter to a public official about a political issue; talking with a public official about a political issue; debating or offering public comment on a scientific issue; debating or offering public comment on a political issue; writing a letter to the editor about a civic or political issue, writing a letter to the editor about a science-related issue. Clearly, these results indicate success of SENCER courses as related to the ideals articulated in List 1.

Concluding Thoughts

As with any innovative project in educational reform, SENCER is a work in progress. To date, a major accomplishment of the SENCER project has been to create an interna-

tional community of educators who are committed to the goal of enhancing students' understanding of science and its central role in addressing important societal issues. This community has included not only mathematicians and scientists, but also writers, historians, anthropologists, and experts in public policy. This inclusiveness reflects the SENCER perspective that science is a necessary component of addressing complex civic issues yet, by itself, is not sufficient.

Acknowledgments

We would like to gratefully acknowledge the National Science Foundation for its continued support for science education. This work is funded by a CCLI National Dissemination Award, DUE-0455586.

Notes

1. SENCER is used both as a noun and as an adjective; both forms have found their way into the language of curriculum reform. The verb to SENCERize was coined at the 2002 Summer Institute, meaning to make something SENCER-like (another new adjective). Our apologies to the grammarians.

2. The selection of chapters is strategic. Those earlier in the textbook form a core that introduces students to the more fundamental concepts in chemistry such as the periodic properties, stoichiometry, molecular shape, and energy.

3. The borders of Arizona, New Mexico, Colorado, and Utah meet at Four Corners. This region is home to several peoples, including the Diné (or Dineh, The People). The name Navajo was given by outsiders.

4. The Morse Academic Plan is named after Samuel F. B. Morse, an early faculty member at New York University. Although now remembered as the inventor of the telegraph, Morse was better known in his lifetime as one of America's foremost portrait painters.

5. The wording of these student learning goals has been refined and updated since the publication of the Energy and the Environment model course in 2001.

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