ACS SYMPOSIUM SERIES

Science Education and Civic Engagement: The Next Level

EDITED BY

Richard D. Sheardy and Wm. David Burns

Science Education and Civic Engagement: The Next Level

ACS SYMPOSIUM SERIES **1121**

Science Education and Civic Engagement: The Next Level

Richard D. Sheardy, Editor
Texas Woman's University
Department of Chemistry and Biochemistry
Denton, Texas

Wm. David Burns, Editor
National Center for Science and Civic Engagement
Washington, DC

Sponsored by the
ACS Division of Chemical Education

American Chemical Society, Washington, DC

Distributed in print by Oxford University Press, Inc.

Library of Congress Cataloging-in-Publication Data

Science education and civic engagement : the next level / Richard D. Sheardy, editor, Texas Woman's University, Department of Chemistry and Biochemistry, Denton, Texas, Wm. David Burns, editor, National Center for Science and Civic Engagement ; sponsored by the ACS Division of Chemical Education.
pages cm. -- (ACS symposium series ; 1121)
Includes bibliographical references and index.
ISBN 978-0-8412-2752-1 (alk. paper)
1. Science--Study and teaching--United States--Congresses. 2. Science teachers--Training of--United States--Congresses. 3. Democracy and science--United States--Congresses.
I. Sheardy, Richard Dean. II. Burns, David (William David)
Q183.3.A1S3534 2012
507.1′073--dc23
2012042602

The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials, ANSI Z39.48n1984.

Distributed in print by Oxford University Press, Inc.

PRINTED IN THE UNITED STATES OF AMERICA

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 242[th] annual meeting of the American Chemical Society in August 2011 at Denver, CO. 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 an opportunity to learn science, to think critically about global issues, and to act as citizen scientists. The contributors to this book have a deep appreciation for science education reform and an understanding of the associated issues.

This volume is a follow up to *Science Education and Civic Engagement: The SENCER Approach* (Edited by Richard D. Sheardy, ACS Symposium Series 1037, 2010) that contained chapters about course redesign, assessment and effective scientific communication. Our new book focuses on how the SENCER approach has been expanded to include not just individual courses, but programs of study.

We 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. We are 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. We extend a warm thank you to Dr. Myles Boylan of the Division of Undergraduate Education at the National Science Foundation for his guidance and counsel over the years. We also acknowledge and thank the National Science Foundation for its continued financial support of this project. Finally, R.D.S. also wishes to acknowledge the encouragement and support of Ann Q. Staton, Dean of the College of Arts and Sciences at Texas Woman's University.

Richard D. Sheardy
National SENCER Leadership Fellow
Professor and Chair
Department of Chemistry and Physics
Texas Woman's University
Denton, Texas 76204

Wm. David Burns
Executive Director
National Center for Science Education and Civic Engagement

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Acknowledgment

Our cover art was inspired by a poster for a 2008 SENCER Conference at Texas Woman's University that was designed by Michael Paul McGuire, then project coordinator for the College of Arts and Sciences.

Editors' Biographies

Richard D. Sheardy

Richard D. Sheardy was born in Lake Orion, MI and received his B.S. in Chemistry Education at Michigan State University. After earning his Ph.D. in organic chemistry at University of Florida, he had a Post Doctoral Fellowship in biophysics at University of Rochester. Sheardy began his academic career at the Hazleton Campus of Penn State University and then went to Seton Hall University where he initiated his research on DNA conformation and stability. In 2006, Sheardy moved to Texas Woman's University where he is currently Professor and Chair of the Department of Chemistry and Physics. He teaches freshman chemistry, organic chemistry, physical chemistry and biochemistry and continues his research focusing on the structure, stability and ligand binding properties of DNA quadruplexes. Sheardy is on the Board of Directors for the Calorimetry Conference, is Co-Director of SENCER Center for Innovation-Southwest and is a SENCER Leadership Fellow.

Wm. David Burns

Wm. David Burns is the executive director of the National Center for Science and Civic Engagement, co-founder and principal investigator (PI) of SENCER, publisher of Science Education and Civic Engagement - An International Journal, and professor of general studies at the Harrisburg University of Science and Technology. David also serves as PI of SENCER-ISE II, a new NSF-supported project to connect formal science education with informal science educators and PI of the Science and Civic Engagement Western Network, an initiative supported by the W.M. Keck Foundation. Prior to founding the National Center, David served as a senior policy director for the Association of American Colleges and Universities. He was an administrator Rutgers University from 1973 to 1994.

Chapter 1

Meeting the Challenges of Large Scale Educational Reform: SENCER and the Problem of "Knowledge Inequality"

Wm. David Burns*

1606 New Hampshire Avenue N.W., Washington, DC 20009
***E-mail: david.burns@sencer.net**

Knowledge inequality should concern us. The gaps between "knowledge haves" and "knowledge have-nots" are growing despite greater access to higher education. This chapter describes a proven strategy to improve STEM learning and increase the capacity of students to engage with some of the great civic challenges of our times. Following a brief description of the SENCER approach, the limitations of even extraordinary single courses are identified. To achieve transformative, durable learning, the author argues that larger-scale curricular and post-curricular reforms are required. These approaches should be designed to enable students to: (1) stick with hard things longer, (2) pursue answers, not be persuaded to adopt a particular answer, (3) imagine, make, interrogate, and explore new connections, and (4) do more than one thing at once. In addition to offering strategies for increasing knowledge and capacity for effective participation in a modern democracy, the author offers a mini-guide to this volume, identifying where readers can find more detailed treatments of the issues raised and topics discussed here.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

The great American pragmatist philosopher and father of American psychology, William James, once observed that…

> …the difference between an interesting and a tedious teacher consists in little more than the inventiveness by which the one is able to mediate… associations and connections, and in the dullness in discovering such transitions which the other shows. One teacher's mind will fairly coruscate (*1*) with points of connection between the new lesson and the circumstances of the [students'] other experience. Anecdotes and reminiscences will abound in her talk; and the shuttle of interest will shoot backward and forward, weaving the new and the old together in a lively and entertaining way. Another teacher has no such inventive fertility, and his lesson will always be a dead and heavy thing (*2*).

In this chapter, I will describe a program—and identify opportunities for broader scale applications of an approach—that helps students and teachers make connections between basic disciplinary learning and the biggest questions of our day. It encourages and allows them become the "weavers" that James conjures in that marvelous quote. This approach is quite timely, as the gaps between the "knowledge haves" and the "knowledge have-nots" seem to be growing despite the fact that access to formal learning has expanded.

This chapter will also serve as a modest guide to the rest of this volume as I will suggest where in the book you will find more detailed examples and expositions of the elements I am touching on in this overview.

Knowledge Inequality

In the months leading up to the ACS Symposium from which this volume originates, and in the last year, much was being and has been made of the growing gaps in income inequality and their implication for our future as a democracy. These economic "slopes," though steep, pale in comparison to "knowledge inequality." The consequences to democracy are no less significant.

Inequality in income is depicted by something called a Gini coefficient. According to the World Bank, the Gini-coefficient of inequality:

> is the most commonly used measure of inequality. The coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, all others have none) (*3*).

By the way, Gini emerged from its customary obscurity when Jon Stewart referenced it in a *Daily Show* segment in which he situated the inequality score for the US somewhere near that of Cameroon. The "we are the 99%" movement helped make the concept a household word.

Knowledge inequality, however, isn't quite so simple. It is not "representable" by a Gini-coefficient, since, unlike wealth, we lack a currency or single symbolic unit (like money or income) that offers us this reductive opportunity. I use the term here to refer to what we all know. That is, on any given topic or subject (whether it be native plants of Texas, or string theory, evolution, the practice of hydrofracking, or the poetics of Aristotle), there are differences, sometimes vast differences, between levels of knowledge (not to mention "operationalizable understandings" if you will) both within "a field" (which is a collection of experts), and the space outside the field (the much vaster universe of novices). If we were to measure all the gaps between those with the most and those with the least understandings on any given topic our Gini-coefficient would approach and might even reach 1.0, I presume. Ironically, if we were to be able to sum all of these individual "scores" into one gigantic coefficient, it would probably come much closer to "0"—a perfect equality of a sort that no one should desire! (Such a condition offers us a good argument for collaboration or at least sharing, don't you think?)

Faced with this enormous and growing inequality, among expert learners to some extent, and surely between expert and novice learners, we are left with the challenge of understanding, then closing, the gaps. We should recognize that our best hope is to move in the direction of graduating students, all of whom will have more highly developed epistemic practices of inquiry, discernment, representation and application and at least some of whom will be able to use these practices to pursue and achieve more "focused" and specific intellectual goals.

Our time with students is so brief and life is so long. Unless you have a formula for creating that one course that will "forever change a student's life" (for the good, I hasten to add: we all know there are courses that achieve a contrary result), it would also be a good idea, I think, to take on two responsibilities: (1) creating broader scale opportunities for students to stay engaged and continue to learn while in college, and (2) helping students become aware of, and accustomed to, using credible and valuable resources in the informal education sector that s/he can access and "rely upon" in the future.

I don't really think our current common approaches have been successful in creating "scientifically literate" graduates (even among those who are STEM majors and surely not among those who are not). "Literacy" is a fairly elusive goal, since, for me, it suggests fluency. Perhaps, with Stephen Toulmin, we can hope for something closer to a capacity for understanding different kinds of "discourses" and arguments—ways of talking about things and ways of asking intelligent questions about the things being talked about.

In any event, this pursuit will require some "material"—that is, some content that can be better understood with different species of disciplinary knowledge and investigative practices and in so doing help a student acquire what we now call the canonical knowledge within a discipline. I would like to suggest that we make that material the most complex, challenging, capacious, civic challenges of our time.

Our first book in the ACS Symposium Series (Science Education and Civic Engagement: The SENCER Approach, Vol. 1037, 2010) explored the SENCER approach at a course level. In the present volume, we consider larger scale applications, identify the conditions that will enable reform, describe anticipated

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

changes in faculty practice and student engagement, and suggest ways that a larger scale program can be assessed, validated, represented, disseminated, and extended beyond the classroom and campus.

The SENCER Approach

This book argues that we can apply the SENCER approach to broader scale curricular reform programs, beyond the creation of single courses, and that we can reduce knowledge inequality through intensive study on topics of relevance. By these means we can encourage the development of the epistemic practices I mentioned earlier, those of inquiry, discernment, representation and application. Beyond their academic value in supporting learning and aiding human understanding, these skills, dispositions, and habits of mind are essential ingredients in the portfolio of capacities necessary to the health of a modern democracy.

SENCER stands for Science Education for New Civic Engagements and Responsibilities. Supported by the National Science Foundation since 2000, we are a national (even international) staff development and, as some would say, faculty empowerment program. SENCER was originally focused on changing how courses for so-called non-majors were taught. (These non-majors are the folks who would rather be anywhere else—at the orthodontist's even—than in a STEM course.)

SENCER now has applications all over the curriculum, from pre-service teacher preparation, as described by Carolyn Viviano, Maria Alderete, Catie Boarts, and Meredith McCarthy of Loyola Marymount in Chapter 8 to a collection of basic and advanced chemistry courses that Doug Latch, Lindsay Whitlow, and Peter Alaimo of Seattle University explain in Chapter 2.

When Karen Oates and I created SENCER we thought we would be helping collaborators change their courses. They did. But what we have subsequently learned is that it was teachers and teaching (and students as scholars, too) who were really changing as a result of engaging in their "SENCERizing their work," as more than one participant has described it. Matt Fisher of St. Vincent College provides us with a personal narrative of this transformation in Chapter 6, while Danielle Kraus Tarka and Janice Ballou of the National Center for Science and Civic Engagement document this transformation more systematically and across the experience of many professors in Chapter 12.

Our collaborators have spurred a migration of SENCER ideals to courses for majors, to whole degree and certificate programs (as described by Jeff Robb and Dick Sheardy of Texas Woman's University in Chapter 4), and even, in a very limited way, into graduate education.

So what is SENCER? The main shift in the SENCER approach over traditional approaches is to emphasize the context (and application) of learning. We use context to get at content. Then we use that content knowledge to spur deeper inquiry and the identification of more comprehensive occasions calling for new applications of knowledge.

We say SENCER instructors teach through complex, capacious topics of civic consequence to the basic canonical disciplinary learning that is desired in a given course or subject area, or to even a topic within a course or subject area.

By the way, we chose "civic issues" as those matters, often contested and unsettled, in the public sphere that a better grasp of STEM learning would be helpful to have in order to conscientiously and effectively engage with some of the great issues of our time. For me, what has become SENCER started with a course on AIDS at Rutgers in the early 1990's, where the instructor taught through HIV to basic biology. For others working with us, the issues that animated the development of a SENCER course have included computer security and privacy, obesity, energy, clean water, catastrophes, food security, African land development, traffic in Los Angeles, and so on. The list is quite extensible, to be sure.

A distinguished chemical educator, Cathy Middlecamp, calls our approach "outside in." This is opposed to practices that, say, start at some sub-atomic level and end up offering an application, post facto. On the SENCER website (www.sencer.net) you will find nearly 50 models that apply the outside/in approach to a wide variety of topics of civic consequence. In Chapter 5 in this volume, Teaching and Learning in Radioactive Landscapes: Nuclear Unclear, Dr. Middlecamp provides a look at SENCER in action at the University of Wisconsin-Madison.

While SENCER is a name we invented for a program that is not as old as my almost 17 year old twin daughters, it is not exactly a new idea, whatever a new idea might be in the 21st century (*4*)! The SENCER approach has deep intellectual roots: in Aristotle, the enlightenment thinkers, the land grant and extension movements, the pragmatism of William James, in constructivist approaches to learning and knowledge production, and in the work of modern cognitive scientists and learning specialists like John Bransford and Rick Duschl, both of whom have advised the SENCER program.

More than anything else, SENCER responds to a problem. That problem is that, for far too many students, the standard approaches to teaching are leaving too many folks behind, to coin a phrase. This view is backed up by another expert, one of my daughters. To my question "what is science?" posed to her while she was in elementary school, she tersely responded: "it's just definitions, Daddy." This is especially true in so-called introductory courses, a genuine misnomer for the students whose total exposure to college level STEM instruction may be limited to four semesters. These courses are the true "bridges to nowhere." Afterwards, students are often left wondering what the course was even about, let alone why they had to take it. Too often they increase knowledge inequality.

We wanted to change this. We have good reasons for doing so, not the least of which is the depressing condition of public discourse on science. Another reason, one of concern within education, itself, is the (AP-abetted, perhaps) disturbing state of disconnection between testing performance and genuine understanding that is being observed in many of our best students.

Jay Labov of the National Research Council tells the story of one such student who had gone to the trouble of memorizing all, yes all, the reactions in the Kreb's cycle while she was in high school. She came to his Colby College office to complain that Jay hadn't asked students to recall them on his exam. She seemed angry and was breathing pretty heavily. When Jay asked her if she knew why she was breathing so hard, she had no idea. For him, and for all of us who care about learning, this is an embarrassing story. It's a story about a failure in instruction and perhaps a larger problem, which is the missing link between instruction and knowledge transfer, between knowing and doing.

To make an analogy, as an approach, SENCER is not a medication or a therapy (something specific and sensitive that if applied in a given dose to a given person for specific duration), as it is a kind of pedagogical wellness regimen: a set of principles, practices, "exercises" and approaches, that, if followed, will optimize health. Just as within a wellness framework there are times when very specific therapeutics are indicated and where they are crucial for health maintenance, within SENCER courses and programs there will be occasions when very specific tutorials and other approaches ("just in time mathematics" instruction, peer led learning, for example) may be helpful. But the overall approach is one that starts with something we call the SENCER ideals, ideals that are more end-state descriptors than prescriptions for specific actions.

The SENCER project is sometimes frustrating for those looking for so-called magic bullets, but that is a condition we are prepared to endure, because we believe our approach preserves the widest scope for both imagination and authority for the professor and his/her students. Our program occupies that special place somewhere between orthodoxy and anarchy, which is exactly where you'll find democracy. (As I noted earlier, you can find the SENCER ideals and lots more at www.sencer.net.)

Our rubric suggests our methods in detail. In a nutshell, we begin with assessing interest (that is, what is interesting to the student? to the teacher?). Next, we take that topic of interest (the complex, capacious, contested civic issue) and break it down into its component elements. Then we think about the intellectual goals we have for the course or program. What are the elements of canonical disciplinary knowledge we hope students will learn or skills we hope students will develop and refine? As Professor Barbara Tewksbury of Hamilton College is fond of asking: What do we hope students will be able to do as a result of having this intellectual experience?

After we identify interest, an issue, and our learning goals and their outcomes we turn to how to teach and what we can do to help students accomplish the learning. This makes us think about pedagogy: what are the best strategies for linking the first three elements? We think of pedagogical strategies as tools for getting a job done. Is a lecture the right tool for this aim? Is a community-based research project the right approach for this goal? (Because we talk of civic engagement, some folks imagine that service learning is what you might add to a science course to make it a SENCER course. This isn't how we see it; rather, we see academically-based service learning as just one powerful pedagogical strategy that can be employed.)

Having chosen the teaching and learning tools to enable learning and maintain interest, we are nearly ready to set up the course or program. What remains are two additional elements: the first is planning for some kind of action component. This responds to the question: what do I do with what I have learned?

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

We have seen SENCER projects that keep this in the "anticipatory" mode: what might I do, how can I rehearse an action, draft a letter to the editor, for example. Often, the action moves to something much more "participatory," from drafting a letter to sending it, or from investigating how to become a member of the local water quality board to actually becoming a member, that kind of thing. In Chapter 7, Professor of Chemistry Garon Smith of the University of Montana offers us creative approaches to bring robust and meaningful civic engagement activities even in "mass-education" programs at a research university.

The last element is, of course, one that accompanies and underlies each other element: that is assessment. How do we know that what we are doing is effective? We have helped develop an online tool, the SENCER–SALG (*5*), to assist with this. It supplements the many other valuable assessment tools available. To my mind, this is a much simpler matter than many folks think. What we need to do is to channel the feisty former mayor of New York, and persistently and frequently ask the Ed Koch question: How am I doing? Or maybe better still, how are we doing? This is the best shorthand way of describing formative assessment I know.

Of course, for assessment to work, it is vitally important to act on the answers you get to your questions. Indeed, we are happy to note that we have evidence that faculty members who are actively engaged in assessing how students think the activities and strategies that their teachers have incorporated in their courses are using that evidence to modify their practices. Trace Jordan of New York University helps us understand this in his research report in Chapter 13, while Stephen Carroll and Glenn Odenbrett describe a larger scale, multi-institutional application of SALG in Chapter 14.

To summarize, when learning situations embody the SENCER ideals and these six design elements, students experience learning that is:

(1) <u>Real</u>—SENCER courses and programs are about real things (*6*). They teach through real things. They are not trapped in abstractions. They do not insist of memorizations of vocabulary/terminology as necessary preparation for engaging in real inquiry. They help students proceed to deeper and more comprehensive understandings by encouraging students to ask "how do we know this?" questions.

(2) <u>Relevant</u>— SENCER courses and programs start by being about things that matter to students (and teachers), issues that interest them, and matters that have some impact on their lives. They help students explore and interrogate the connections between their own interests and matters that have heretofore not attracted their interest.

(3) <u>Rigorous</u>— SENCER courses and programs set high expectations for student achievement and engagement. They model the "values" embodied in scientific practice and show how these values relate to the values embraced in democratic practice. They do not confuse failure with rigor, but associate the success of the student with the success of the instruction.

(4) <u>Responsible</u>— SENCER courses and programs respect the complexity of the issues that frame the course as well as the diversity of views and

values that students bring to the course. Because the basic maneuver within this kind of approach is making something that heretofore may have been considered a private matter into a public matter, special care must be taken to preserve that zone of personal freedom in which students can come to their own conclusions and develop their own opinions on complex matters.

Broader Applications

I believe a successful education empowers students to (1) stick with hard things longer, (2) pursue answers, not be persuaded to adopt a particular answer, (3) imagine, make, interrogate, and explore new connections, and (4) do more than one thing at once. These are big goals and a lot to ask from single courses of three months duration. Of course we know that such goals are achievable: indeed we have several dozen national models and hundreds of examples to prove it.

This volume and the Symposium in which many of these papers originally appeared, however, were designed to begin to move beyond the limitations of single course approaches. We remain interested in programs for students who intend no further study in the STEM fields than is absolutely required of them for degree attainment in some other field or area. But we are also interested in foundational or introductory courses in the STEM fields.

To kick off the consideration of these issues, I will offer my own very brief list of possibilities, with particular attention to one challenge that I want to pose that I hope may take us in a promising direction.

First a word on the limitations: faculty members working on SENCER courses designed to serve as introductions to disciplines sometimes report difficulties finding a civic topic that "stretches" successfully over all of the content knowledge they wish to cover. This is not such a problem when designers are working on an integrative science platform. It can be a problem where a narrow disciplinary orientation is imposed. Other limitations have a "facts of life" quality to them:

- Single courses are brief, offering a relatively short time to focus on a big issue. Just as a student's research project is getting started, the course is over. Or, as often happens, if the topic that the student is studying has a "life cycle" that is not in sync with the course, how does one do the work?
- For the student taking a general education course, there is the common problem of that course's disconnectedness to other courses, to study in one's major, etc.
- Often there is no logical or easily discernible sequence in courses or clearly expressed connection to other courses being taken at the same time. Even when there is a sequence, as within majors study, the current likelihood that the sequence will create continuity of interest for the student is low. (A notable exception to this is the EPICS program in engineering, where students begin on a real project and carry on in that project over several semesters. But this is, of course, not general

education, but professional education, where such an integrated approach seems to me like the only really promising way to go.)

- Interdisciplinary teaching is not well supported administratively; collaborations are difficult to manage and sustain.
- Current budgetary constraints and staffing shortages are limiting the development of "new courses" and state-level mandates on course credit transferability are encouraging "sameness" (standardization) in course content, as opposed to the more hand –crafted courses that SENCER courses traditionally are.

The broader applications I will describe here and that our co-others detail in subsequent chapters are promising responses to these limitations. More than merely responding to curricular and academic administrative challenges, I think the strategies outlined in this volume will reduce knowledge inequality. By so doing, we will improve our democracy (*7*, *8*).

Here's my very short list of broader strategies:

Linked Courses

I have seen some very creative approaches to taking an issue, making it the subject of more than one course (often in different disciplines altogether, like English and biology) and then linking the content, coordinating assignments and assessments, and even trading places in the classrooms. In one college where team teaching is essentially unsupported by the faculty-administrative labor contract, faculty members appeared in one another's classes at regular intervals, so all the classes were covered, but the students got the benefit of one form of team teaching and both professors got to know the students in both classes. An emerging project that is particularly compelling is being created by faculty teams at the United States Military Academy, West Point. To promote interdisciplinary education that leads to the development of graduates who can face unscripted conditions nimbly and effectively, and to help achieve an institutional goal to be "energy net zero" by the middle of the next decade, West Point professors have created an "energy spine" to organize learning within mathematics and chemistry sequences, with related efforts in communication and leadership development. To represent this initiative as a linked course reflects not its ambition, which is large and potentially truly transformative, but rather derives from the fact that the program is just beginning this year. I would say, "please stay tuned." The West Point effort is likely to become a model to be adapted broadly.

Course Intersections

This is the term invented by three innovative professors (two in chemistry) at Vassar. This SENCER model is described as follows:

> The Course Intersection brings two classes together, a Chemistry course in Instrumental Analysis, the other an Introduction to Urban Studies,

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

around the single problem of lead exposure in urban environments. The class in Instrumental Analysis enrolls primarily Chemistry majors, while the Urban Studies class attracts students who are interested in public policy. For three weeks at the end of the semester, both groups must pool their knowledge and work collaboratively to study a real-world problem-the levels and effects of lead exposure in their own urban environment. The resulting collaboration provides students with an opportunity to put their academic learning in a wider social and political context, while demonstrating the power of interdisciplinary investigation (*10*).

You will find an exciting variation on this model in Chapter 2, Incorporating an Environmental Research Project Across Three STEM Courses: A Collaboration between Ecology, Organic Chemistry, and Analytical Chemistry Students, by the three chemists from Seattle University, already mentioned.

Learning Communities

This species of broader application is exceedingly well-described (*11*). Indeed, some of the examples I have already cited (for example, linked courses, clusters) are, according to the folks at the Washington Center, types of learning communities. I use the term learning communities here in the way I first learned it from my SENCER co-founder, Karen Oates, who has been a national leader in the learning community movement. As a founding dean at New Century College, Karen and her colleagues built a college around the concept of integrated learning, with specific cohorts of students engaged in deeply experiential learning focused on a significant theme. One of the four original SENCER national models, Mysteries of Migration, by Tom Wood and Betsy Gunn, is now joined by several other SENCER models that are models not just of a complex issue, but of the learning community approach (*12*).

Saturation

This is my term for an approach that essentially changes course after course to make them more "SENCERized," so that students are "running into" this pedagogy wherever they go. The Butler University approach is exemplary here (*13*). Also exemplary is the strategy adopted at Indiana State University, where students have been playing a remarkable leadership role and the strategy is supported by the institution's strategic plan. Yet another example of the saturation approach can be found at Roosevelt University in Chicago where, according to its organized, it is now almost impossible to graduate without taking one or more SENCER course. All three of the aforementioned institutions have been recognized for their exemplary work with the William E. Bennett Award for Extraordinary Contributions to Citizen Science. Administrative support is also essential to achieving a "tipping point" in embedding the SENCER ideals in comprehensive curricular reform. In Chapter 3, Dean DonnaJean Fredeen of

Southern Connecticut State University offers us a comprehensive discussion of what it takes to achieve transformative outcomes given what she sees as the opportunities presented by the "changing tides" of curricular reforms.

Certificate Programs

Another way of broadening the effects of learning in individual courses is to identify a set of pathways that, if followed successfully, would qualify the student for some kind of validating and testamentary credential, like a certificate. This approach seems best suited for thematic study of the sort that SENCER's focus on a complex, contested civic issue represents. A certificate is something short of a major but different from a minor in that it is not a "discipline specific" marker of achievement. As mentioned earlier, Texas Woman's University is creating a trans-disciplinary civic engagement certificate program that would help link and integrate a variety of SENCER and other course and non-course experiences, activities, and accomplishments. TWU's efforts are detailed in Chapter 4.

Foundational Majors Courses

I know I said I wanted to move beyond individual courses, but I think SENCERizing foundational courses would lead to broader applications and increased capacity for making connections for students. It is easy for me to give dozens of examples of conversations with STEM faculty members who were alarmed at how narrowly students seem to view learning, how disconnected learning is from real things, how disconnected aspects of learning are from one another, and so forth. To the student, the course looks like a set of hurdles to be jumped before a final exam. Then it's on to a different venue or maybe a different sport altogether. Organizing foundational courses around themes that have poorly defined borders, lots of connections with other ways of knowing, lots of "beach rubble" to quote a favorite Sappho fragment, as opposed to the beautifully laid out record of disciplinary accomplishments, might just enable connections to what June Osborn named "multidisciplinary trouble" (*14*). This challenge is one that we hope to make the subject of a future Symposium and, if we can assemble a set of compelling examples, perhaps another book in this series.

Getting There, Knowing That We Are Succeeding, and Designing New Pathways and Strategies To Reduce Knowledge Inequality

Encouraging these broader applications entails attention to several dimensions of what some have called the change process, or the diffusion of innovation.

Assessing Effectiveness

Knowing that what we are doing is effective and lives up to its promise is essential in the reform process because, as the political theorist, Michael Oakeshott, observed in his essay *On Being Conservative*:

> First, innovation entails certain loss and possible gain, therefore the onus of proof, to show that the proposed change may be on the whole expected to be beneficial, rests on the would-be innovator (*15*).

The obligation that Oakeshott enunciates and that we in the SENCER community accept was echoed in a much more self-interested way by those with whom we first collaborated to create SENCER. They argued that one reason why we needed a national program was to develop a set of assessment strategies and instruments that would help us learn—beyond what we could determine individually—if this approach were living up to the expectations we had for it. That led us to invest in the development of the Student Assessment of Learning Gains instrument described earlier. Several chapters of this book, notably Chapters 12, 13, and 14, are devoted to addressing this concern, reporting on results, and describing broader applications.

Disseminating Innovations

Sharing the results of our work with others, among students, within the academic community, and with society at large are also fundamental to achieving our larger goals of reducing knowledge inequality. To increase what we can all know about things that are hard to know, the SENCER program has identified a series of strategies, some new and some tried and true. In Chapter 10, LeAnne Shepard, Nicole Wallace and Cynthia Maguire of Texas Woman's University, describe an innovative approach to translating the esoteric (expert) knowledge as depicted in typical academic poster presentations into ordinary (novice) language. This iterative, student-led project not only promotes effective communication and increased learning, but it helps to assure that the "expert" really knows what he/she is talking about. As any scholar knows, trying to teach what you know is a very good way of finding out if you really know what you are talking about.

How to move from communicating about individual courses to representing larger applications so they will be of use to the broader academic community, is the challenge addressed by Eliza Reilly, the general editor of the SENCER model series, in Chapter 11. Meeting this challenge is fundamental to achieving the goal of transformation that our sponsors at the National Science Foundation expect of us. Reilly suggests approaches that do not overwhelm would-be innovators, take advantage of advances in communication, and respect professional autonomy, academic authority, institutional diversity.

Moving in New Directions

As I noted much earlier, our current model of relying on one or two courses to provide the foundation for a lifetime engagement with persistently vexing, let alone yet-to-be-described, scientifically-inflected complex problems, is doomed to fail us, even when those one or two courses are truly magnificent. Such minimal and "been there/done that" experiences are likely to increase, not close, a knowledge inequality gap. Conditions will improve if the promising larger scale interventions and programs described in this book are enacted. But college only lasts so long—too long, some might say, but in any event, the years at one's alma mater are a small fraction of an average person's lifetime. Creating so-called "life-long learners" is not a new challenge to our society. Given the extraordinary opportunities provided by search engines and the Internet, this reach needn't exceed our grasp.

But what is it that we are likely to grasp? And when will we know that what we have grasped (the information or analysis we have "retrieved") has legitimacy and integrity? Some very impressive reports from the National Academies have begun to address this "information literacy" issue in connection with STEM learning. In the SENCER community and at our National Center for Science and Civic Engagement, we have embarked on a project to explore what we hope will be a fruitful avenue to expand and extend learning by our graduates, while strengthening the bonds between so-called formal education (what most schools and colleges do) and informal education (what museums, arboreta, zoos, and science journalists do). We are looking to use the complex, capacious unsolved problems of public consequence ("civic engagement") to forge linkages between the formal and informal sectors and create pathways for students to access the high quality "instruction" that our informal science education enterprises offer across our students' life spans. Alan Friedman and Ellen Mappen describe our nascent efforts to explore and create these pathways in Chapter 9.

Nurturing Community

Creating and sustaining what Etienne Wenger described a community of practice has been fundamental to our approach, an approach that is sympathetic, *simpatico,* with democratic practice, itself. As I have noted, at the level of individual development, Matt Fisher describes a personal transformation, while DonnaJean Fredeen considers institutional transformation. The conditions, as identified by a host of "transformation" experts, require the creation of a "community." Malcolm Gladwell puts it bluntly: "If you want to bring a fundamental change in people's belief and behavior…you need to create a community around them where those new beliefs can be practiced and expressed and nurtured" (*16*). In the concluding chapter of our book (Chapter 15), Amy Shachter and J.J. Barnett of Santa Clara University apply an innovative diffusion model to examine SENCER's work. They tell us if they think we've crossed the "chasm" between those who were attracted to the SENCER idea from the start and what we might call the next, and much larger population, those who were open to thinking about our approach, embracing it and modifying it to make it better. In the views of some change theorists, these folks (the "pragmatists" in some descriptions of them) determine the success of an innovation. I do not want to spoil the suspense of your finding out for yourself how our Santa Clara University colleagues think we're doing.

"The World Is Not Parsed Out Like a College Curriculum."

Can we organize a college student's general education around one or another example of multidisciplinary trouble? To conclude this chapter, I want to suggest one additional possible larger scale application of the SENCER approach. This application is inspired by Woody McKenzie's pithy and precise observation about the disconnection between the world and the college curriculum (*17*). I have noted elsewhere that:

> The best SENCER topics are so complex and so embody the idea of multidisciplinary trouble that they require the intellectual power of a variety of disciplines for their full elucidation and exploration. They break traditional boundaries and make the case for inter-disciplinary inquiry, global learning, critical thinking, collaboration, and continuous attention and exertion. Even though the courses are often taught as introductory excursions in learning or capstone projects, as Robert Full has observed, they look like advanced research because their intellectual challenges resemble those being tackled by high-end research (*18*). They are essentially interdisciplinary, so they are more like the world itself than a typical undergraduate curriculum.

I want to suggest that we think about a very robust version of the cluster concept that might enable a student to fulfill a "multidisciplinary trouble" civic engagement competency as his/her general education option. Can we parse the general education program (and the foundational courses for STEM majors, as well) as the world is parsed? Can we teach history, economics, geography, writing, and mathematics by answering a question like: when did folks once called settlers become folks we now call immigrants? Can we teach chemistry, political science, geology, writing and mathematics by asking whether dioxin-laden sediment should be dredged? Or physics, communication, psychology and a host of other things by seriously answering questions about nuclear power, and comparing our answers with other forms of energy and their historical and geopolitical significance? Is looking at the multidisciplinary problem of diabetes, let's say, a near perfect vehicle for organizing a pre-medical education, one that looks at individual and population health, economics, culture (and improves writing, thinking, and reasoning, to boot)? Can we take great regional resource issues and frame a program around them that would help us answer a question like: Should we take water from the Great Lakes and pipe it to Texas, maybe in exchange for oil?

You can round this out on your own. The possibilities are endless. I mentioned the promising work at West Point on energy—no trivial matter and one that is as painfully ironic as it is practical necessity to solve (*19*). The problems we face as a society and as participants in a global community are enormous. The potential benefits in reducing knowledge inequality are great, just as the potential contributions to our civic discourse and democratic welfare are substantial. It's work that needs to be done.

Please note that my argument in this chapter and the work we have done in SENCER is no simple-minded and clichéd call for tearing down disciplinary silos. (Having grown up in a farming family, I know the value of silos!) Neither is this a plea to turn everybody into a generalist. Rather it is a suggestion that enables and I hope promotes a greater attention to and success at integration, at connected learning. Following E.M. Forster's injunction, William Cronon has written:

> If I could pick just one phrase that would answer the question of what it means to be a liberally educated person surely this would be it: Only Connect…It's the core project. Without it, all else fails" (*20*).

Indeed, this book is a plea to—and we hope a guide for—responding to what is truly interesting and truly important to students, to us, to our communities and regions. It is also an opportunity to engage in the kind of sparkling teaching—the deft weaving—that James so eloquently described in the passage I quoted at the outset of this chapter.

Lastly, borrowing again from American pragmatism, we see the ideas presented in this volume as a chance to apply science to learning and to put that learning in the service of our democracy. In doing so, we will reduce knowledge inequality and we will generate what James called a greater "cash value" for something we should value, general and liberal education, at a time when the market for it is sadly depressed.

References

1. A great old word, now sadly out of use: "to give forth flashes of light" to sparkle or glitter, like sparks flying.
2. James, W. *Talks to Teachers*; Henry Holt and Company: New York, 1894.
3. The World Bank. *Measuring Inequality*. http://go.worldbank.org/KUPDM2SVE0.
4. Emig, J. *The Web of Meaning*; Boynton Cook Heinemann: Portsmouth, NH, 1983. Janet Emig writes: "…I have fully described the notion that the presence of an explicit or at least tacit intellectual tradition is requisite for a full and self-respecting inquiry paradigm, as acknowledgement of that tradition is requisite for any self-respecting paradigm inhabitant…The reason the only decent and scholarly ploy is to know and to acknowledge one's sources is that, at this very late date in human intellectual history, it is deeply unlikely that at least those of us who work in the humanities—that non-cumulative endeavor—will have a wholly original idea…." (p 166).

5. See Student Assessment of Their Learning Gains. http://salgsite.org/.
6. I use the term course and program, but really want to broaden that idea out to the kinds of larger applications that we are here to discuss. So when you hear or read "course" (where it is not used about a specific course) please think of this as a pronoun for a larger notion: the learning situation being created by the professor and students and experienced by them.
7. Burns, W. D. But you needed me: Reflections on the premises, purposes, lessons learned, and ethos of SENCER, part 1. *Science Education and Civic Engagement: An International Journal*. **2011**, *3*, 5−12. http://www.seceij.net/seceij/summer11/burns_part_1_yo.html.
8. Burns, W. D. Knowledge to make our democracy. *Liberal Education*. **2002**, *88*, 20−27. http://www.sencer.net/About/pdfs/KnowledgetoMakeOurDemocracy.pdf.
9. See SENCER, DC Symposium 2008. http://www.sencer.net/Symposia/dcsymposium2008.cfm .
10. Batur, P.; Belli, S.; Smart, C. *Chemistry and Policy: A Course Intersection*; SENCER Model Series; Reilly, E., Ed.; http://serc.carleton.edu/sencer/chemistry_policy/index.html.
11. See Washington Center for Improving the Quality of Undergraduate Education. http://www.evergreen.edu/washcenter/lcfaq.htm.
12. See The SENCER Model Series. http://www.sencer.net/Resources/models.cfm.
13. See Butler University Incorporates Civic Engagement into Core Curriculum. http://www.sencer.net/institutes/pdfs/SSI_2010/CS_BennettButler_Kirsch.pdf.
14. Osborn, J. E. The AIDS epidemic: Multidisciplinary trouble. *N. Engl. J. Med.* **1986**, *314*, 779–82.
15. Oakeshott, M. On Being Conservative. In *Rationalism in Politics and Other Essays*; Liberty Fund: Indianapolis, IN, 1991; pp 411−412.
16. Gladwell, M. *The Tipping Point: How Little Things Can Make a Big Difference*; Little, Brown and Company: New York, 2000.
17. McKenzie, W. Personal correspondence with author, 2008. Woody McKenzie, a SENCER Leadership Fellow from Lynchburg College, wrote: "SENCER is essentially an outlet for me to validate my own ideas of what a valid liberal arts education should include in the information age. More emphasis should be placed on interdisciplinary courses. The world is not parsed out like a college curriculum."
18. See, for example, SSI 2007 Participants Work to Improve Education for All Students. http://www.sencer.net/Institutes/pdfs/SSI_2007/Presentations/Plenary_Full.pdf.
19. We are told that it takes seven gallons of fuel to transport one gallon of fuel to Afghanistan. That wars that some say have their origins in access to energy or energy security threaten the lives of the West Point graduates and their comrades who are called to fight in them, makes the energy spine of their curriculum much more than an exercise in curricular transformation. For our colleagues at West Point and many others these are matters of life and death.
20. Cronon, W. HIV, Health and Liberal Education. In *Learning for Our Common Health*; Burns, W. D. , Ed.; Association of American Colleges and Universities: Washington, DC, 1999; p 50.

Chapter 2

Incorporating an Environmental Research Project Across Three STEM Courses: A Collaboration between Ecology, Organic Chemistry, and Analytical Chemistry Students

Douglas E. Latch,*,[1] W. Lindsay Whitlow,*,[2] and Peter J. Alaimo[1]

[1]Chemistry Department, Seattle University, Seattle, Washington 98122
[2]Biology Department, Seattle University, Seattle, Washington 98122
***E-mails: latchd@seattleu.edu (D.L.), whitlowl@seattleu.edu (W.L.W.)**

Our collaborative research and integrated teaching programs focus on understanding chemical dynamics, ecological impacts, and human health risks posed by pyrethroid pesticides in aquatic ecosystems. We accomplish this in our courses by designing laboratory projects in which our undergraduates participate in field sampling, chemical analyses, and laboratory experiments that advance our research goals. This approach involves the research groups of three faculty and scores of students enrolled in Ecology, Organic Chemistry Lab III, and Instrumental Analysis annually. We have designed the project, in part, to demonstrate to our students the benefits of collaborating across disciplines. In this contribution, we aim to describe how this project can serve as a model for faculty who are interested in developing a similar approach.

Background

Science that addresses complex issues is often inherently interdisciplinary. Such research frequently requires effective collaborations to accomplish work that combines diverse methods. Furthermore, teams of collaborators are often needed to synthesize the results, which leads to an improved understanding of the complex and dynamic systems under investigation. We work with Seattle University undergraduates in three courses across chemistry and

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

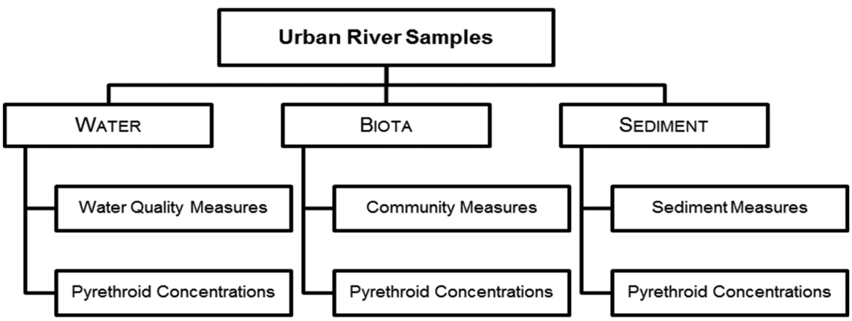
biology to examine relationships between contaminant concentrations, aquatic environmental conditions, benthic invertebrate populations, and human health concerns in the Duwamish industrial waterway in Seattle, WA. As part of this project, we also coordinate with community organizations to determine priority sites for sampling and identify stakeholders for communicating our findings. Our research objective of elucidating how pesticides in aquatic habitats impact ecosystem and human health merges with our teaching objective of modeling how scientific collaborations can be used to generate data and to better understand these complex systems.

Research on urban waterways demonstrates that greater runoff volume, greater temperature extremes, and more contamination results from increased urban and industrial development (*1*). Studies examining restoration efforts have highlighted the challenges faced in urban estuaries, since significantly altered watersheds feed these systems. As a result, projects in such settings typically focus on decreasing stressors (*2*). Within industrial waterways, smaller restoration areas are often targeted with aims to provide small-scale improvements in aquatic habitat to facilitate improvements in water quality (*3*).

A prime example of an urban waterway that has been substantially altered and degraded is the lower Duwamish River. Channelized and industrialized as Seattle developed over the twentieth century, this estuary was designated as an EPA Superfund site in 2001 (*4*). Through industrialization, the river lost its natural meanders, 92% of the estuary was filled, and 90% of the floodplain no longer floods on a regular basis (*5*). Besides physical changes, industrial and municipal activities produced high levels of legacy contaminants in the sediment, such as heavy metals, PCBs, and DDT (*6*). Despite the extent of alteration, the Duwamish still provides important aquatic habitat and a migration corridor for fish, invertebrates, and birds. Hence, restoration efforts have focused on specific shoreline sections of the river to dredge contaminated soil, to re-grade shoreline and streambed, and to seed plants (*7*). These relatively small-scale efforts have largely been driven by concern for public health and decline in salmon stocks (*2*). Recent work investigating these restored areas has suggested some success with salmon and invertebrate use, with aims to clarify future strategies (*8*).

We have initiated a program to determine how a class of emerging contaminants, namely pyrethroid pesticides, affects the Duwamish estuary ecosystem. Pyrethroids comprise a class of pesticides that are currently used in hundreds of agricultural, construction, commercial and household products (*9*). They have emerged as the insecticide of choice following the U.S. ban on organochlorine products in the 1970s-1980s, and the subsequent ban on their replacement, organophosphates. Recently, several papers have reported pyrethroid concentrations in natural waterways at levels that are toxic to the indigenous organisms (*10–16*). The sources of pyrethroids in waterways include spray drift, combined sewer overflow (CSO), and runoff from agriculture, golf courses, road medians, lawns, and gardens.

Pesticide monitoring in urban-dominated creeks often focuses on the water column because many high-use pesticides such as organophosphates are relatively water-soluble. For this reason, and because of the more difficult analyses associated with extracting solid samples, we have initially targeted our work on water samples that can be analyzed easily by students. Because pyrethroids are far more hydrophobic than organophosphates (log $K_{OC} \approx$ 5-6) (*17*), this presents a challenge we aim to address through a combination of measuring pyrethroids in these water samples and future sediment and tissue analyses. The expectation that these compounds should partition into sediment and biological tissues has been demonstrated (*18*, *19*). Consequently, it is important to monitor pyrethroid concentrations in multiple environmental compartments (e.g., in the water column, sediments, and biological tissues) in an urban estuary, though few recent studies have addressed this issue (*16*, *19*, *20*). Knowledge of pyrethroid concentrations in the ecosystem compartments of food sources and primary habitat is especially important to understand how pyrethroids affect food webs (Scheme 1). Our project aims to quantify pyrethroid concentrations in the different environmental compartments depicted in Scheme 1 and to assess the impacts that they have on indigenous organisms in the Duwamish waterway.



Scheme 1. Schematic depiction of our approach to studying the effects of pyrethroid pesticides on the Duwamish industrial waterway.

The success of this project *depends* on the active participation of undergraduate students— all Seattle University students enrolled in ecology, third quarter organic chemistry laboratory, and instrumental analysis are involved through their respective courses, as are many undergraduate research students working under direct mentorship of the faculty. In this chapter, we describe our study of contaminants in aquatic ecosystems as a model for faculty who are interested in developing similar collaborative research-in-teaching curricula.

In the following sections, we describe the following: (*i*) an overview of the scientific methods used, (*ii*) the specific courses involved and their respective learning outcomes, (*iii*) the design and logistics of our collaboration, (*iv*) some representative scientific results to demonstrate the quality of the data, and (*v*) some reflections on how this project enhanced the student experience vis-à-vis our learning outcomes.

Scientific Approach

We have developed a method to quantify pyrethroid concentrations in the water compartment of the ecosystem through field collections and laboratory work. Our method was adapted from the recent CALFED final report on the analysis of pyrethroid pesticides in environmental samples (*21*). This CALFED report will also serve as a guide as we extend our work to quantify pyrethroids in other environmental compartments such as sediment and tissue. The resulting analysis method was developed by students in our research groups and in the courses described later in this chapter. A summary of our procedure follows. The specific tasks assigned to students from the different courses are described later. Field sites are located across the lower Duwamish River where we have sampled water and measured ecological variables over the past five years. Water is collected in amber glass bottles, due to the photosensitivity and hydrophobicity of pyrethroids, and sterilized by filtration through 0.20 μm filters. We employ a solid phase extraction (SPE) protocol to concentrate the hydrophobic compounds contained in the water samples in preparation for trace level chemical analysis. We elute the pyrethroids from the SPE cartridges, use a stream of nitrogen gas and gentle heating to remove the elution solvent, and redissolve the eluted mixture of compounds in 1 mL ethyl acetate, thereby concentrating the pyrethroids 1000-fold. The effectiveness of our method is monitored through the use of two isotopically-enriched standards and external calibration standards. After the water samples have been filtered, 50 ng of *trans*-permethrin-$^{13}C_6$ is added to our 1.00 L sample aliquots. After the samples have been concentrated through SPE and redissolved in EtOAc, a 50 ng spike of *cis*-permethrin-$^{13}C_6$ is added. In this way, the *trans*-permethrin-$^{13}C_6$ reports the effectiveness of all of the method steps that occur following filtration while the *cis*-permethrin-$^{13}C_6$ serves as an injection standard.

We have also developed an effective method for collecting reliable data on water quality across multiple sites in the lower Duwamish River. Through a consistent sampling regimen, including regular intervals (i.e., monthly) and responses to storm events, we can quantify relevant water quality parameters that potentially affect pyrethroid concentrations. With each water sample, the battery of measurements includes: temperature, pH, dissolved oxygen (HACH HQ40d probes); nitrate, nitrite, ammonia, total nitrogen, phosphate, total phosphorus, sulphur, copper, COD, turbidity (HACH SR2800 field spectrophotometer); and salinity (refractometer). Using this sampling protocol, we build on our preliminary results that suggest CSOs are potential sources for higher turbidity, higher nitrate, and lower oxygen levels. By detecting pyrethroid concentrations in ecosystem compartments and measuring water quality, we can identify parameters corresponding to pyrethroid sources, fates, and impacts. By designing our project to include temporal, spatial, and chemical variations among samples, we are able to make inferences about how pyrethroid pesticides impact the environmental health of the Duwamish.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Institutional Context

Our collaboration is between Ecology, Organic Chemistry Lab III, and Instrumental Analysis, which are standard courses that are common to most American undergraduate chemistry or biology curricula. As such, the topics covered in each course are fairly standard relative to corresponding courses at other universities. Because Seattle University operates on the quarter system, these courses each meet for 12 weeks; however, conducting a similar collaboration on the semester schedule would likely alleviate some of the time constraints that we sometimes confront. We conduct our collaboration during the spring quarter because all three courses are offered each spring; this enables meaningful and timely interaction between students in the different courses. A brief description of each course follows, some of which is summarized in Table 1.

Table 1. Summary of information about each course in our collaboration

	Ecology	*Organic Chemistry Lab III*	*Instrumental Analysis*
Course enrollment	20 - 25	60 - 80	12 - 18
Number of sections	1	5 - 7	1
Lab hours / week	4h	3h	7h (2 x 3.5h)
Student body [a]	Jr. & Sr.	So. & Jr.	Jr. & Sr.
Weeks involved [b]	1 - 4	1	5 - 6

[a] So. = sophomores; Jr. = juniors; Sr. = seniors. [b] Number of weeks that students in each course work on this collaborative project.

Our ecology course (BIOL 470) is a one-quarter course taken primarily by junior and senior biology majors. This course introduces undergraduates to interactions between organisms in biological communities and the relationship of biological communities to the environment. Ecology meets for three hours of lecture and four hours of laboratory per week. Lecture topics include population growth and regulation, competition and predation, community energetics and nutrient cycling, comparative ecosystem analysis, and ecosystem evolution. Laboratory exercises include field sampling techniques, experimental population manipulations, and ecosystem modeling. The initial field labs introduce students to methods and relevant issues at local study sites through meetings with community partners, sample collection, and data analysis. Based on these introductions, students design independent and team projects to further investigate more specific hypotheses.

Organic Chemistry III Lab (CHEM 347) is the third lab course in a standard year-long organic chemistry series and each section meets once weekly for three hours. As the terminal course in a year-long series, the third quarter is dedicated to research projects that change periodically according to the interests of the faculty who are teaching the course. Applications of organic chemistry to other fields are emphasized, and recent research projects have links to fields such as medicinal

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

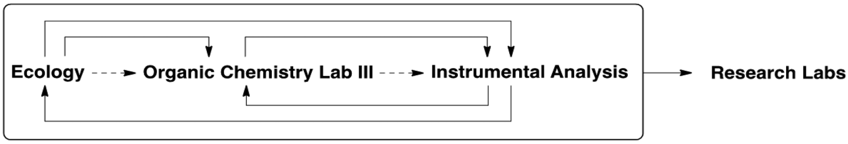
chemistry, biochemistry, cell biology, materials science, environmental chemistry, and food science. This is enabled by the design of the three quarter series wherein the first quarter lab course focuses on organic chemistry lab techniques, and the second quarter lab is dedicated to performing organic chemistry experiments taken from the primary literature.

Instrumental Analysis (CHEM 426) is the second of two analytical chemistry courses offered at Seattle University and it meets for two lecture hours and approximately seven laboratory hours per week. Scientific concepts covered include the theory, methods, and techniques of spectrophotometric, chromatographic, and micro-analytical procedures in instrumental analysis as well as introductory statistics and quality assurance. Examples from environmental chemistry are often used in the lecture as a means to introduce students to these scientific concepts. Most of the laboratory exercises focus on open-ended environmental research questions. The students work together in small groups and perform their experiments on a rotating basis. Each group has two lab periods (one week) to complete a given study before advancing to the next experiment. Experiments at the beginning of the quarter often involve method development and validation, whereas those later in the quarter focus on quantitative analysis using the methods developed by earlier groups.

Design and Logistics of Our Collaboration

Our initial aim was to design a project that provided an example of *bona fide* scientific collaboration, addressed a local environmental issue, and supported understanding of fundamental course concepts, within the constraints of available laboratory time. Other than serving as a useful example of course concepts, by design, this project had no direct impact on the lecture portion of these courses. Overall, this collaborative project requires the entire academic quarter to conduct; however, the amount of time dedicated to the project in any one course is less than 20% of the total time in lab. Thus students in each course conduct many additional unrelated experiments over the 12-week quarter. Before the quarter starts, the faculty members plan the logistics of the collaboration, starting with the dates of sample collection by the Ecology students, a decision that is partially dependent on tidal conditions. Because we have multiple sections of Organic Chemistry Lab III, it takes an entire week to conduct the reverse-phased solid phase extraction (RP SPE), elution and evaporation. Ideally the sample collection and SPE can be completed in the first two to three weeks of the quarter, leaving ample time (3-5 weeks) for students in Instrumental Analysis to optimize LC and MS parameters, and then conduct their measurements. This leaves us only a few weeks to gather students across courses, permitting them to share and discuss their data. Scheme 2 illustrates the sharing of samples and dissemination of data between students; the faculty involved and their research groups provide oversight on all aspects of the project.

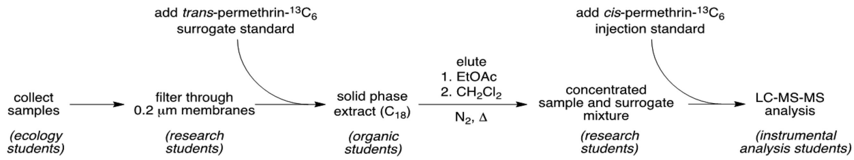
In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.



Scheme 2. Diagram illustrating the sharing of samples (dashed arrows) and data (solid arrows) between student groups participating in this research project.

Students' experience of the collaboration begins when the students from all three courses (*ca.* 100) assemble for an evening viewing of *Poisoned Waters*, a PBS Frontline documentary (available on DVD) about anthropogenic pollution in the Puget Sound and Chesapeake Bay. This serves to introduce students to the need for scientific collaboration in general, and also to instill interest, curiosity, and a common baseline of background knowledge about this collaborative project. The Frontline documentary is also noteworthy for our students because the Duwamish drains into the Puget Sound; their study site directly impacts one of the locations under scrutiny in the documentary. Another way we generate student interest and a sense of connection to the research project is by organizing a field trip to the Duwamish River. About halfway through the term, we arrange for all the students to participate in an ongoing community service project aimed at restoring the river. To simplify our workload, we work with Duwamish Alive, a non-profit citizen's group that aims to protect and restore habitat in the Puget Sound. Students meet with the leaders of these citizen's groups to ask questions about local environmental issues, and they participate in restoration activities (e.g., invasive plant removal and water quality monitoring).

Student participation in the research portion of this study starts with ecology students collecting river water samples (*ca.* 40 – 60 L) from several sites along the Duwamish River. In addition to the samples that are brought back to the lab, the Ecology students also conduct field measurements of numerous abiotic measures of ecological import (e.g. pH, temperature, dissolved O_2, salinity, total suspended solids, [Cu], [NO_3^-] and [PO_4^{3-}]) as well as biotic ones (e.g., density and size of amphipod, isopod and polychaete benthic invertebrates). The river water samples are then sterile filtered within 24 h by our research students to prevent microbial degradation during storage. Each pair of organic chemistry students conducts reverse-phased solid phase extraction (RP SPE) on one river water sample (1 L each) using commercially available SPE cartridges. They then elute the retained mixture of organic compounds using an organic solvent, and evaporate the solvent, leaving a solid residue. This residue is provided to the students in Instrumental Analysis, who dissolve it in a small volume of organic solvent and analyze the resulting solution by LC-MS-MS, quantifying the concentration of each member of a panel of 5 pyrethroids and two isotopically-enriched standards. This flow of material and data between the groups of students is depicted in Scheme 3.



Scheme 3. Diagram illustrating the collection, processing, and analysis of Duwamish water samples by the various groups of undergraduate students participating in this research project.

The data generated are communicated between the Ecology and Instrumental Analysis students so that (*i*) they can practice their presentation skills, and (*ii*) they can make use of the composite data, as appropriate. For example, in presentations and posters generated by students for a final symposium, field ecological data with laboratory chemistry data were combined to demonstrate that sites with detectable pyrethroid concentrations are higher in water turbidity, suggesting surface runoff as a likely source. Because Organic Chemistry students are not ready for the types and volume of data generated by students in the other two, more advanced, courses, we supply Organic Chemistry Lab III students with only the mass spectral data, which they use to identify the pyrethroids detected. Using mass spectral data to characterize organic molecules is an appropriate assignment for these students and solidifies the link between the Organic Chemistry and Instrumental Analysis courses.

Representative Scientific Results

Although this chapter is focused on providing a model to faculty for future course development, we wish to provide examples of the type of data our students have generated in this study. Our results thus far indicate working with students across the three courses enables us to quantify low levels of pyrethroids in water, quantify differences in water quality, and investigate relationships with invertebrate densities. We have found differences among study sites suggesting potential sources from surface runoff associated with urban development (Figure 1). Elevated levels of turbidity, nitrate, and phosphate at the Hamm Creek site suggest potential higher volumes of runoff compared with other sites. Since runoff often carries higher loads of suspended solids, turbidity functions as an effective indicator of runoff, and these solids may often carry excess nutrients (e.g., nitrate and phosphate), which can have negative consequences for aquatic systems through eutrophication and hypoxia. Due to the chemical nature of the pyrethroids, they may also be more likely to accumulate in areas with increased turbidity and runoff.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

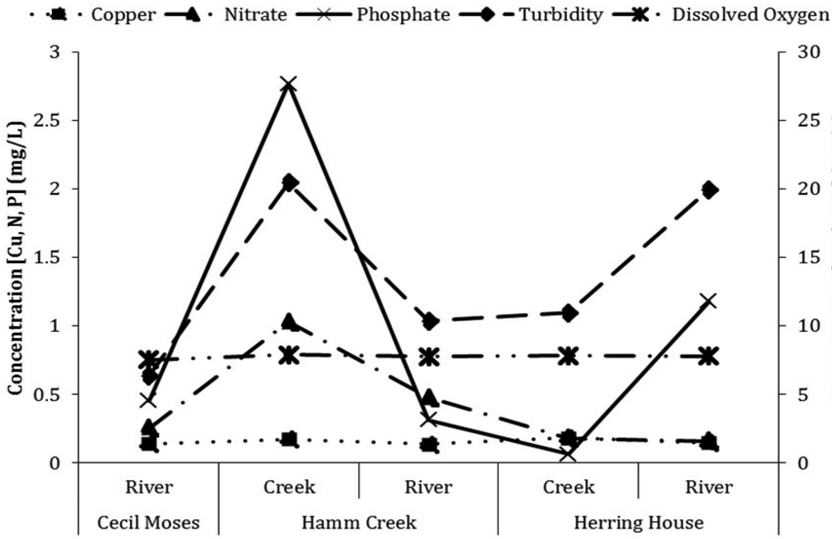


Figure 1. Data collected by students during the ecology class exemplifying the variation among sites and the similarities in concentrations patterns between turbidity, phosphate, and nitrate, suggesting potential runoff sources.

In order to connect our data on water quality and ecological measures with aquatic chemistry, we have developed a selective and sensitive SPE-LC-MS-MS method to monitor selected pyrethroids (*cis*- and *trans*-permethrin, bifenthrin, cyhalothrin, and cypermethrin isomers) in our post-SPE samples. Figure 2 shows a calibration curve for these compounds. Instrument detection limits for these analytes are approximately 5 ng/mL, meaning environmental concentrations of a few ppt (ng/L) are detectable given our SPE concentration step. These detection limits are on par with what others have reported for the more common GC-MS-MS methods used for pyrethroid analysis (*21*). Preliminary tests show that bifenthrin was present at detectable levels. Unfortunately, we were not able to quantify the detected bifenthrin because of poor recoveries of our permethrin-^{13}C standards. After our research students later optimized our analytical procedures, recoveries of spiked standards from Duwamish water were greater than 90%. As our research project progresses, we intend to adapt our LC-MS-MS method to accommodate additional high-use pyrethroids (e.g., deltamethrin, esfenvalerate, and cyfluthrin). All of these analytes can be monitored simultaneously by our analytical instrumentation. Another important area for future development is to adapt our analytical procedures to allow for analysis of pyrethroids from solid samples (i.e., sediment and tissue) given the importance of understanding pyrethroid fates in different compartments within the Duwamish. Work on this analytical challenge provides future students with opportunities to develop, adapt, and test new methods during summer research opportunities. At the end of the school year, all the data generated feed into our research programs, where our research students then build upon the preliminary findings obtained.

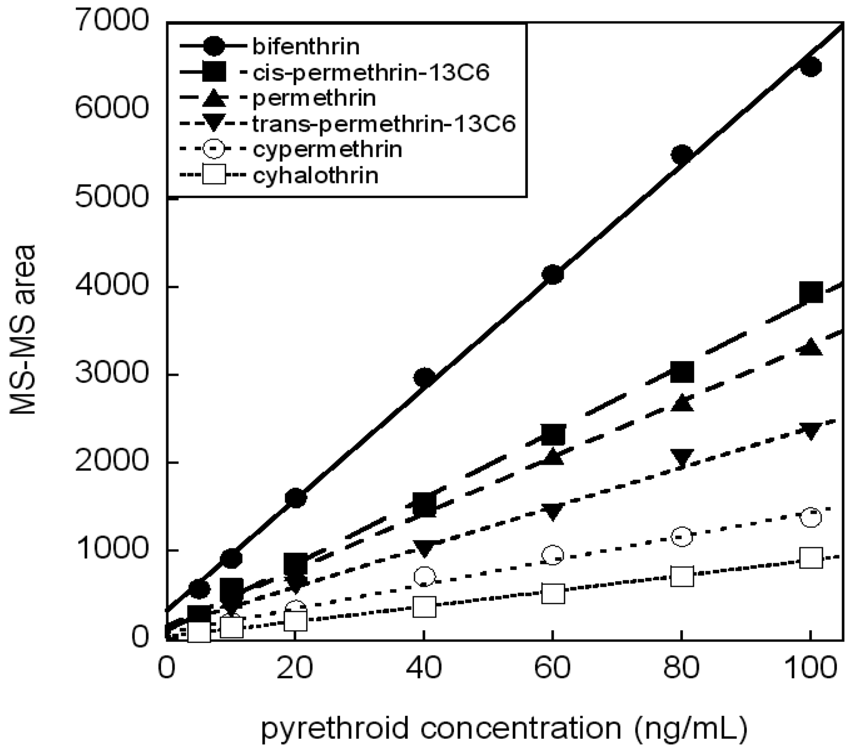


Figure 2. Student generated liquid chromatography-tandem mass spectrometry (LC-MS-MS) calibration curve for selected pyrethroid pesticides.

Reflections on Our Learning Outcomes

This project fits well with the learning objectives of each of our courses. In the Ecology course, the learning outcomes include comprehending fundamental concepts underlying environmental issues, exploring local ecosystems, experiencing essential elements of field research, and contributing to local issues through science. These are matched perfectly by this project that aims to investigate ramifications of emerging environmental contaminants to the aquatic food web of the Duwamish River. During their field work, the Ecology students achieve nearly all of these course goals.

One of the four academic learning outcomes for the organic chemistry students is to "apply the fundamental lab techniques of separation, purification and characterization to investigate current scientific research questions." Participation in this project addresses this learning outcome as students apply their knowledge of thin-layer chromatography, column chromatography, gas chromatography, and mass spectrometry to SPE and LC-MS. In addition, their participation enables

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

an increased throughput of environmental samples, thus allowing for multiple replicates of each measurement and the obtainment of higher quality data by the Ecology and Instrumental Analysis classes. Students in Organic Chemistry Lab III learn about SPE and LC-MS-MS because of their participation in the collaboration. SPE and LC-MS are significantly more specialized than what is typically taught in most sophomore organic chemistry courses; however, they are widely used in many research fields including environmental science, food science, cell biology, natural products chemistry, and medicinal chemistry. Although we would not argue that SPE and/or LC-MS-MS ought to be added to typical organic curricula, we are happy to have our students learn additional and modern techniques such as these. For these reasons, this course almost always involves a few modern techniques, depending on the nature of the research projects the faculty choose to include.

Among the academic learning outcomes for the instrumental analysis are to (*i*) operate sophisticated scientific instruments commonly found in chemistry laboratories; (*ii*) choose and successfully employ appropriate instrumental and calibration techniques depending on the particular experimental parameters; and (*iii*) collect, critique, and use spectroscopic, chromatographic, and mass spectrometric data to determine the identity of unknown analytes and to quantify their concentrations. By using primary samples from this collaborative research project, the students are faced with all the challenges and decisions of doing actual analytical chemistry research. The students gain first-hand experience developing analytical methods and operating highly sophisticated instrumentation. They also learn about MS-MS quantification methods and using isotopically-enriched standards to assess the performance of their analytical method.

Besides meeting the learning objectives of the three courses, the research-based and community-oriented characteristics of this project provide significant advantages to our students. First, our students are excited to work on a real research project. This is especially true for the organic chemistry students, who are mostly sophomores who have not yet had the opportunity to participate in research projects. In addition, our students enjoy the fact that this project focuses on a site that (*i*) is an environmentally disturbed Superfund site; (*ii*) is a real-world problem of local importance; and (*iii*) is a problem that disproportionately affects the racially and economically disadvantaged people who live along the river. These facts help our students to understand how science can be applied to problems that many of them already care about. Finally, this project helps our students to understand the role of meaningful scientific collaboration; throughout this project, students learn that none of the faculty's individual research groups have all the skills and knowledge needed to address the problem of collecting, concentrating, and quantifying emerging contaminants in the Duwamish industrial waterway. This becomes apparent when we gather everyone together and students realize that none of their individual faculty are able to answer all of their questions, a realization that becomes obvious as they see us turn toward each other for advice.

Summary

Taken together, our work with students in our courses assesses contaminant concentrations, water quality, and invertebrate populations across sites to determine ramifications for the foundation of the aquatic food web. To investigate relationships among these factors, we developed protocols in our chemistry courses to measure pyrethroid pesticides across a panel of sites over time. The students have been able to analyze pyrethroid variability within and across sites to explore relationships with invertebrate densities and water quality. Students have also been able to quantify how pyrethroids can interfere with natural responses to predation threats, with ramifications for overall food web dynamics.

Our collaboration is focused on detecting levels of emerging chemical contaminants and monitoring the potential ecological impacts. While always being mindful of our primary research aim of elucidating how anthropogenic chemicals ultimately impact the environmental health of the Duwamish River estuary, we also focus on providing a rich and meaningful learning experience to our undergraduate students. We integrate several areas of inquiry through our collaboration among chemists and ecologists, with particular skills and interests in environmental health sciences. Distinctive components of our project include: work within a Superfund site known to be impacted with legacy pollutants, measuring emerging contaminants using sophisticated instrumentation, investigating ecologically relevant changes in food webs, and carrying out all of this research with undergraduate students across multiple linked science courses. We hope this contribution will serve as a catalyst for future innovative course development.

Acknowledgments

We acknowledge all of our students who have participated in this research project with us. In particular, we thank our research students who have helped us to plan and carry out this collaboration in our courses. We gratefully acknowledge Seattle University's College of Science and Engineering's Dean's Office for providing us with funding to initiate aspects of this project.

References

1. Paul, M. J.; Meyer, J. L. Streams in the urban landscape. *Annu. Rev. Ecol. Syst.* **2001**, *32*, 333.
2. Simenstad, C.; Reed, D.; Ford, M. When is restoration not? Incorporating landscape-scale processes to restore self-sustaining ecosystems in coastal wetland restoration. *Ecol. Eng.* **2006**, *26*, 27.
3. Elliott, M.; Burdon, D.; Hemingway, K. L.; Apitz, S. E. Estuarine, coastal and marine ecosystem restoration: confusing management and science—a revision of concepts. *Estuar. Coast. Shelf Sci.* **2007**, *74*, 349.
4. *NPL Site Narrative for Lower Duwamish Waterway*, 2001. Environmental Protection Agency. http://www.epa.gov/superfund/sites/npl/nar1622.htm.

5. *Watershed Profile: Salmon and the Duwamish/Green Watershed*, 2008. Shared Strategy for Puget Sound. http://www.sharedsalmonstrategy.org/watersheds/watershed-green.htm (accessed December 21, 2008).
6. Trim, H. *Restoring our River; Protecting our Investment: Duwamish River Pollution Source Control*, 2004. Prepared for the Duwamish River Cleanup Coalition. http://www.duwamishcleanup.org/uploads/pdfs/DRCCSourceControlReport.pdf.
7. Simenstad, C.; Tanner, C.; Crandell, C.; White, J.; Cordell, J. Challenges of habitat restoration in a heavily urbanized estuary: Evaluating the investment. *Coastal Res.* **2005**, *40*, 6.
8. Cordell, J.; Toft, J.; Cooksey, M.; Gray, A. Fish assemblages and patterns of Chinook salmon abundance, diet, and growth at restored sites in the Duwamish River. *2005 Juvenile Chinook Duwamish River Studies* **2006**, *2*, 1.
9. Spurlock, F.; Lee, M. Synthetic Pyrethroid Use Patterns, Properties, and Environmental Effects. In *Synthetic Pyrethroids: Occurrence and Behavior in Aquatic Environments*; Gan, J., Spurlock, F., Hendley, P., Weston, D. P., Eds.; ACS Symposium Series 991; American Chemical Society: Washington, DC, 2008; pp 3−25.
10. Thomas, C. R.; Hose, G. C.; Warne, M. St. J.; Lim, R. P. Effects of river water and salinity on the toxicity of deltamethrin to freshwater shrimp, cladoceran, and fish. *Arch. Environ. Contam. Toxicol.* **2008**, *55*, 610.
11. Boone, M. D. Examining the single and interactive effects of three insecticides on amphibian metamorphosis. *Environ. Toxicol. Chem.* **2008**, *27*, 1561.
12. Maul, J. D.; Brennan, A. A.; Harwood, A. D.; Lydy, M. J. Effect of sediment-associated pyrethroids, fipronil, and metabolites on *Chironomus tentans* growth rate, body mass, condition index, immobilization, and survival. *Environ. Toxicol. Chem.* **2008**, *12*, 2582.
13. Macneale, K. H.; Kiffney, P. M.; Sholz, N. L. Pesticides, aquatic food webs, and the conservation of Pacific salmon. *Front. Ecol. Environ.* **2010**, *8*, 475.
14. McLaughlin, N.; Yin, D.; Maltby, L.; Wood, R. M.; Yu, H. Evaluation of sensitivity and specificity of two crustacean biochemical biomarkers. *Environ. Toxicol. Chem.* **2000**, *19*, 2085.
15. McWilliam, R. A.; Baird, D. J. Postexposure feeding depression: A new toxicity endpoint for use in laboratory studies with *Daphnia magna*. *Environ. Toxicol.* **2002**, *21*, 1198.
16. Amweg, E. L.; Weston, D. P.; You, J.; Lydy, M. J. Pyrethroid insecticides and sediment toxicity in urban creeks from California and Tennessee. *Environ. Sci. Technol.* **2006**, *40*, 1700.
17. Laskowski, D. A. Physical and chemical properties of pyrethroids. *Rev. Environ. Contam. Toxicol.* **2002**, *174*, 49.
18. Allan, I. J.; House, W. A.; Parker, A.; Carter, J. E. Diffusion of the synthetic pyrethroid permethrin into bed-sediments. *Environ. Sci. Technol.* **2005**, *39*, 523.
19. Mekebri, A.; Crane, D. B.; Blondina, G. J.; Oros, D. R.; Rocca, J. L. Extraction and analysis methods for the determination of pyrethroid

insecticides in surface water, sediments, and biological tissues at environmentally relevant concentrations. *Bull. Environ. Contam. Toxicol.* **2008**, *80*, 455.

20. Hladik, M. L.; Kuivila, K. M. Assessing the occurrence and distribution of pyrethroids in water and suspended sediments. *J. Agric. Food Chem.* **2009**, *57*, 9079.
21. Hladik, M. *Methods Development for the Analysis of Pyrethroid Pesticides in Environmental Samples*; Final Report for CALFED (ERP-02-P42); 2007; p 98.

Chapter 3

Weaving a Tapestry of Change: Implementing SENCER on Campus

DonnaJean A. Fredeen*

Southern Connecticut State University, 501 Crescent Street, New Haven, Connecticut 06515
***E-mail: Fredeend1@southernct.edu**

Publication Date (Web): December 18, 2012 | doi: 10.1021/bk-2012-1121.ch003

Those familiar with the goals of SENCER and those who attend the regional meetings and Summer Institutes understand the transformative impact this approach has on teaching science. And while these individuals eagerly embrace SENCER and revise courses to incorporate the SENCER approach, many face the arduous task of convincing their colleagues and administrators that SENCER is a worthwhile investment. Leading change in institutions steeped in tradition can be difficult, yet some institutions do have success in implementing SENCER throughout the STEM disciplines. This chapter discusses strategies which have proven successful in implementing SENCER at a public, comprehensive university and weaves together leadership and marketing theories which can lead to a tapestry of program and institutional change.

Deans often find that science and mathematics requirements within general education programs are viewed with disdain by faculty and students alike, and student enrollment is governed by the need to "get the requirement out of the way." Student opinion surveys and comments indicate dissatisfaction with these courses, frequently noting the uselessness of the subject matter and questioning the need to know the material. It is, however, possible to change the tide regarding such attitudes by creating a campus culture in which faculty move away from the traditional pedagogical approaches that often emulate their own education and toward those approaches which truly engage students in scientific understanding

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

of the world around them. Creation of such a culture requires artful change leadership on the part of key faculty members, department chairpersons, and/or the administration.

While this chapter discusses successful strategies that have aided in the implementation of SENCER on our campus, I would not necessarily market it as a guide for leading change. It may appear that I had a plan that was carefully executed. However, the truth follows Lord Polonius' comment "Though this be madness, yet there is method in it." Only in retrospect and through some research into the study of change leadership and marketing theory does an actual "method" emerge that illustrates how the SENCER ideals have been implemented in the science classrooms at Southern Connecticut State University (SCSU). This chapter presents the context, theory and practice at SCSU which, when they converged, created an opportunity to diffuse SENCER into the STEM curriculum. While I believe we have made great progress, much still needs to be done.

Context

Southern Connecticut State University, a member of the Connecticut State Colleges and University (ConnSCU) System, is a comprehensive metropolitan public university offering degrees in 40 undergraduate programs and 46 graduate programs. Southern also offers a sixth year diploma in several special areas and a doctorate of education in educational leadership and nursing. Current full-time and part-time enrollment is 11,200. Undergraduate degrees in physical anthropology, biology, chemistry, computer science, earth science, mathematics, and physics are offered through the School of Arts & Sciences. In addition, we offer minors in environmental studies and marine studies, as well as graduate degrees in biology, chemistry and science education. All secondary education programs are housed within the respective departments in Arts & Sciences. We have a total of 73 faculty members in mathematics and the sciences and a current count of 919 undergraduate and graduate majors, with 47% of these majors being women and 28% members of under-represented groups. The majority of science students major in biology (326), computer science (199), and mathematics (174). The current number of chemistry majors is 66. The chemistry department at SCSU recently revised its undergraduate and graduate program to include a B.S./M.S. (4+1) option and added a Professional Science Masters concentration to the graduate program. In addition, the department added recitation sections to the general chemistry courses and is administering the ACS exams in these courses as part of the university wide assessment program.

Our acceptance rate into medical schools is approximately 67% and our acceptance rate into Ph.D. programs is approximately 90%. In spring of 2007, the Board of Trustees for Connecticut State University (now incorporated into the ConnSCU system) approved the establishment of the Center for Coastal and Marine Studies and the Center for Excellence in Mathematics and Science at SCSU. Faculty are actively involved in research and often include undergraduate and graduate students in their projects.

Prior to Fall 2011, the general education program at SCSU was a traditional program with requirements distributed among disciplinary lines. Students were required to complete three to four credits in Natural Science A (biology and earth science) and three to four credits in Natural Science B (chemistry and physics). We have a large nursing program which requires 24 credits in biology, chemistry and physics. All of the general education science classes matched Carl Wieman's description of a traditional science class (*1*). A professor stands in front of a large passive group of students who are copiously taking notes. The students go home and work end-of-chapter problems in their textbook and take exams that closely resemble those problems. The students complete laboratory exercises and may connect the experimental results to the lecture's content (depending upon the laboratory instructor).

Attempts to discuss pedagogy with the science faculty were met with mixed reviews. Faculty in the Physics Department have been, and continue to be, very involved in science education and well-versed in issues pertaining to student learning. At the other end of the spectrum, we have faculty who very clearly express their satisfaction with Wieman's science classroom description.

> "I provide the most up-to-date material relevant to my discipline. I do not believe in 'outcome' based learning as you understand it. I run my courses following the disciplines of the people who trained me. So far I think that I have been pretty successful. If you have complaints from students concerning my professional competence, please put them in writing so that I can adequately address them. Lastly, I am not interested in the 'Scholarship of Teaching and Learning' and will answer no questions concerning it."

To paraphrase, if it worked for me, it will work for my students. Granted, many faculty employing traditional teaching methods in the classroom have a loyal following of students, particularly in the major. And, very rarely do I receive student complaints regarding any science faculty.

As the former chairperson of the chemistry department, I long held the belief that we offered a high quality program for our majors. I hate to admit that I did not give much thought to the non-major course the department offered. That particular course was offered in a lecture-laboratory demonstration format to a very large audience, usually 200 students. While I was never pleased with the idea that students did not participate in laboratory work, I knew that the professor responsible for the course did connect chemical concepts to aspects of our students' lives. As the university progressed towards the implementation of assessment, I was assigned the task of coordinating the establishment of goals and objectives for the Natural Science B requirement in the General Education program. This work quickly dissipated due to a lack of understanding the importance of assessment in faculty work. (It was, after all, the mid-1990's.)

In 1998, after assuming the role of Dean of Arts & Sciences, I convinced the Undergraduate Curriculum Forum of the need to revise the General Education program and to take a more scholarly approach in so doing. (This program was established in 1977 and two attempts to revise the program failed in 1992 and

1994.) The process of benchmarking national trends was greatly enhanced by our participation in the Association of American Colleges and Universities (AAC&U).

I first heard of SENCER while attending the 2002 national AAC&U meeting. As we were planning the goals and objectives of our new Liberal Education Program, I was concerned that we would continue to have introductory, watered-down versions of science majors' courses offered as the science requirements. It was apparent to me that we needed to find a new approach to teaching science to non-majors, one that could improve the scientific literacy of our students. I was extremely dissatisfied with the status quo and wanted change. This change was also needed in the Honors College science offering, "The Idea of Nature." This course compares ancient and modern science, and examines the role of experimentation and the concepts and meanings of science. For many years, it was offered with both a lecture and laboratory component. By 2004, the content of the course had veered into the domain of the philosophy of science.

The director of the Honors College and I applied to and were accepted as an advance team at the 2004 SENCER Summer Institute. Our goal was to implement some of the SENCER approach in an Honors College course in the spring 2005 semester. From the standpoint of E. M. Rogers' "Diffusion of Innovation" change leadership theory, the Honors College director, unknowingly, was taking on the role of an "innovator," uncomfortable with the status quo and eager to try new things. I became the "change agent," the individual attempting to influence the decision to bring the SENCER innovation to SCSU (*2*).

Theory

Further evidence for the virtues of SENCER is found in the "Handbook of the Undergraduate Curriculum: A Comprehensive Guide to Purposes, Structures, Practices, and Change." Chapter 13 outlines the need for curricular reform projects in the sciences. Gene Wubbels and Joan Girgus call for the development of science courses "that focus on understanding science through a primary lens of real-world problems or other contexts, usually with a multidisciplinary or interdisciplinary stance" (*3*). I also found, in Chapter 31, "Strategies for Change," a very concise summary of E. M. Rogers' "Diffusion of Innovation" theory and its application to higher education (*4*). I was surprised to learn that our efforts at changing the pedagogical approaches in teaching science as well as our efforts to reform general education, fell in step with a marketing theory first published in 1962. In learning about this theory, I began to learn of other approaches to leading change. I'll briefly describe Rogers' theory along with "Kotter's Eight Stage Process for Leading Change," "The Tipping Point," and "Crossing the Chasm" for those of you who may be interested in using such theories to lead change in your department and/or at your institution.

In "Leading Change," John P. Kotter provides an eight step process for transforming institutions which has, at its core, the fundamental goal of tackling the many obstacles that often prevent change from occurring: organizational culture, bureaucracy, politics, distrust, fear of the unknown, etc. These eight stages (Figure 1) are associated with the eight fundamental errors that typically thwart change in any organization (*5*).

While Kotter provides a well-tested process for leading change in any institutions, E. M. Rogers ("Diffusion of Innovation"), Malcolm Gladwell ("Tipping Point"), and Geoffrey A. Moore ("Crossing the Chasm") identify the roles of individuals in the process and offer further insight to overcoming the eight common errors and obstacles Kotter highlights. Weaving these theories together provides a tapestry of cultural change that embraces the need to continually innovate.

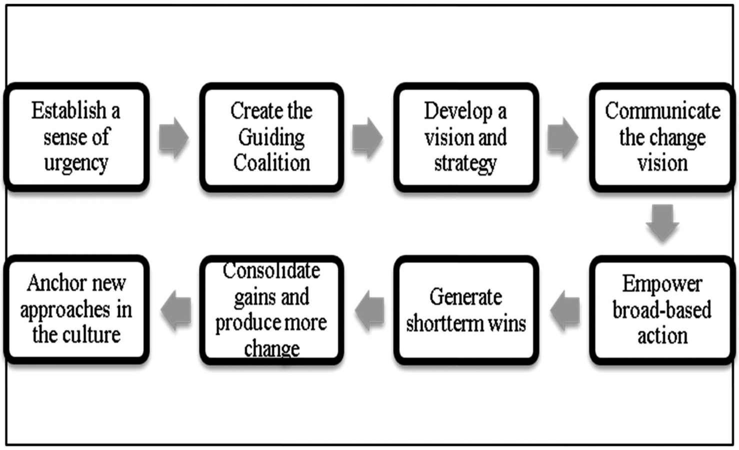


Figure 1. Kotter's Eight Stage Process.

Diffusion is "The process by which an innovation is communicated through certain channels over time among the members of a social system" (*2*). An innovation is a new idea, practice, or object that represents change to members of an organization. The innovation must provide a relative advantage to the adopter and be compatible with the social system's values. It is also helpful if the innovation is relatively simple and one that can be adopted in part or in an easy sequence. In addition, the innovation should be one that is either observable or easily piloted, given that every organization is made up of individuals who are pragmatic in approaching change (*2*).

One very important characteristic of innovation (or change) is the fact that it can be contagious, and we can study innovation in the same way we study epidemics. "Ideas and products and messages and behaviors spread just like viruses do" (*6*). And, just like viruses, there is a point, the *tipping point*, when everything changes. The tipping point is influenced by the Law of the Few, the Stickiness Factor, and the Power of Context provided for the innovation. In order to "infect" people with innovation, they need to be exposed to people who have extraordinary personnel connections, a message that sticks, and have the innovation placed in an important context to the organization (*6*). A comparison of Kotter's eight stage process for leading change to Rogers' diffusion of innovation reveals many parallels between the two. Lessons from Gladwell and Moore are

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

also embedded within the eight stages and diffusion process. E. M. Rogers, *et.al.*, describes the steps for diffusion of an innovation (Figure 2) as 1) learning of the innovation, 2) forming an attitude about the innovation, 3) adoption of the innovation, 4) implementation of the innovation, and 5) confirmation that the decision to adopt was correct. Usually, an individual identifies a need before learning of an innovation; however, it is not uncommon for an individual or organization to learn of an innovation and then match that innovation to a problem (*2*).

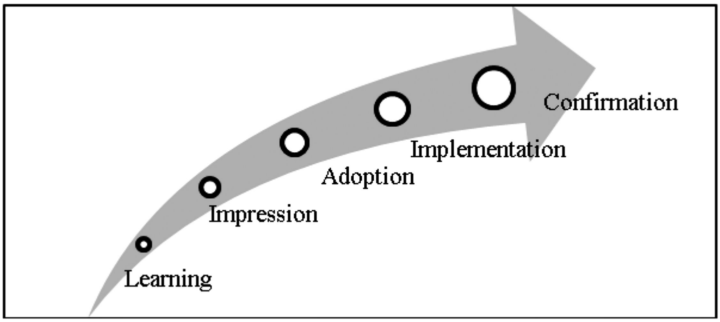


Figure 2. Diffusion of Innovation Steps.

Within the first two steps of the diffusion process, we find Kotter's first two steps of establishing a sense of urgency and creating a guiding coalition. Additionally, we find the first lesson of Gladwell's Tipping Point, the need to reframe the way we think such as taking an abstract problem and presenting it as a social dilemma (*6*). The process of adopting and implementing an innovation is entwined with stage 3 (developing a vision and strategy), stage four (communicating the change vision), and stage five (empowering broad based action) of Kotter's process. Also wrapped into stage three is Gladwell's second lesson that those who create epidemics (those who develop a strategy or vision for change) do what they think is right and believe change is possible (*6*).

The entire process of implementing change requires understanding the characteristics of those who would adopt the innovation, taking advantage of those who are among "the Few," creating a sticky message and the right context, and wrapping the innovation into a whole product. Rogers categorizes individuals within the organization by the role they assume in communicating or adopting the innovation. (Figure 3) Each category points to a particular step in either the diffusion process or Kotter's eight stages. These categories come under the headings of change agents, innovators, early adopters (which includes opinion leaders), the early majority, the later majority, and laggards. (I personally prefer to refer to the laggards as the more traditional among our colleagues or as I once heard at a conference, the CAVE dwellers, **C**olleagues **A**gainst **V**irtually **E**verything.)

The change agent is the individual responsible for establishing a sense of urgency through identification and discussions of major opportunities, crises, or potential crises. [This individual will then recommend an innovation to meet the identified opportunity or crises. The change agent tries to influence the adoption of the innovation and facilitates the exchange of information between those considering the innovation and those who created the innovation. In addition to creating the intent to change, the change agent works to have the intent transformed into action. The change agent's success depends upon the credibility of the change agent and the compatibility of the innovation with the need for change (*2*). The change agent should carefully select those who will be part of the guiding coalition.

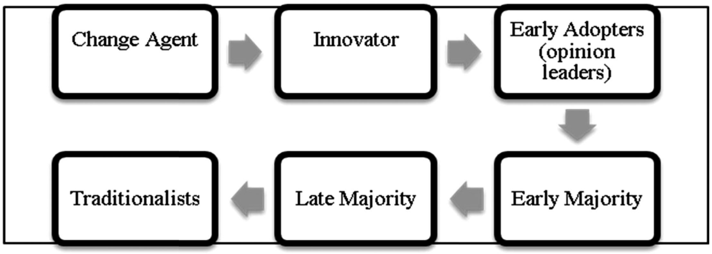


Figure 3. Faculty Roles in the Change Process.

In creating a guiding coalition, it is important to identify a group of people with enough influence and resources to lead the change. This group needs to work together as a close knit team that is highly visible to the organization (*5*). Members of this group include innovators, opinion leaders, and the early adopters. It may be beneficial to include a laggard in this group in an effort to co-opt your detractors. However, such individuals need to be carefully managed and should be considered a leader among his/her laggard colleagues. An innovator is a daring individual, willing to take risks and well connected to networks outside the social system. This individual is uncomfortable with the status quo, less resistant to change, and eager to try new ideas. Usually, the innovator does not belong to the group identified as needing the innovation and, therefore, may not be respected by the group members (*2*). The innovator is the first to adopt an innovation and can increase the group's awareness of the innovation. The role of the innovator to diffusing innovation is the same as the role of kindling to igniting a fire.

Opinion leaders, who are innovative but not innovators, have a unique and influential position within the group. These individuals usually have greater contact with the change agent and are more actively involved in the social system. If the opinion leader becomes too innovative (deviates too much from the system's norms), s/he will lose his/her credibility with the group (*2*). The opinion leader plays a crucial role in the process of introducing the innovation to the faculty. Furthermore, adopting innovation requires careful delivery of the new idea. Faculty are more willing to listen to new ideas that are well researched and backed by impressive evidence. The most persuasive opinion leaders are "those whose expertise, experience, or social role establishes them as credible sources of information" (*4*). Given the long-standing tradition of shared governance in higher education, it is best to have the opinion leaders come from the faculty.

Therefore, the dean or chairperson's role is one of the change agent, to identify the opinion leaders and have them carry the message to the faculty.

Opinion leaders are those individuals that Gladwell describes as "the Few." These individuals are very social, knowledgeable, and influential. They are the people who, once they become aware of a particular innovation, use his/her personality, energy, and social connections to spread the epidemic. As Gladwell states, "Any kind of social epidemic is heavily dependent on the involvement of people with a particular and rare set of social gifts" (*6*). (Anyone who has attended a SENCER Summer Institute will automatically think of David Burns when reading this statement!) Gladwell further categorizes "the Few" (thus creating a sub-category for opinion leaders) into Connectors, Mavens, and Salespeople.

Connectors are individuals with the ability to bring together people from different worlds, tying together heterophilius groups (groups with different attributes such as education, social status, etc.) (*7*). Connectors are members of these heterophilius groups and as such illustrate the strength of the weak tie theory (*2*, *6*). Linking heterophilius groups is very important in the diffusion of innovations as these networks represent weak ties that convey information about the innovation. The acquaintances of the connectors are weak ties to each other and represent a network of social power. A connector with many weak ties is very powerful in his/her role as an opinion leader as these weak ties represent an opportunity to spread the innovation. "The closer an idea or a product comes to a Connector, the more power and opportunity it has as well" (*6*).

Maven is a Yiddish word meaning "one who accumulates knowledge." This person can easily spark word-of-mouth epidemics due to his vast knowledge base, desire to help others solve problem, and ability to connect people to the innovation. The maven plays a special role in the diffusion process given that his knowledge of the innovation can create motivation for adoption. Salespeople, those individuals with the persuasive skills to influence others of the need for and importance of the innovation, are just as important as connectors and mavens.

Most often, these opinion leaders are found among the early adopters of an innovation. Early adopters are more integrated into the group's social system, are considered role models, and are highly respected by their peers. These individuals decrease the uncertainty of an innovation by providing a subjective evaluation. They also represent the group most targeted by the change agent to speed up the adoption process. Early adopters match the innovation to a strategic opportunity and create a project that gains high visibility (*7*). Other characteristics that are typically found in this group include: charisma, highly motivated, recently tenured and promoted, and effective at bringing message to others (connectors, mavens, and salespeople). Early adopters tend to start with a pilot project which allows one to work in stages and build in milestones, leading to other projects.

Innovators, opinion leaders, and early adopters, the guiding coalition, are the individuals who begin the change process. Once an innovator becomes aware of an innovation, his/her responsibility is to evaluate the innovation and appreciate the value of the innovation. The early adopters understand the impact of the innovation on the institution, and the opinion leaders (connectors, mavens, and salespeople) translate and communicate the message of the innovators and early adopters so the innovation, the virus, becomes an epidemic. This guiding coalition links the

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

innovation to the institution by developing a vision. The vision needs to direct the diffusion of the innovation; therefore, the guiding coalition also needs to develop strategies for achieving the vision that take into consideration the characteristics of the innovation.

Kotter defines an effective vision as one that is imaginable, desirable, feasible, and easily communicable (*5*). When creating such visions, institutions often find themselves dealing with creative tension, the gap between the vision (our hopes for the future) and the current reality. This tension can be resolved by either raising reality towards the vision or lowering the vision towards the current reality (*8*). The guiding coalition needs to focus their energy to resolve this creative tension by moving reality towards the vision. This resolution is usually accomplished through effective communication of the change vision and the empowerment of broad based action (stages four and five).

Moving from communication of the change vision through the next two stages requires the adoption of the innovation by the early majority. The early majority are the most numerous, approximately 1/3 of all the adopters. These individuals are an important link in the diffusion process; however, they are not opinion leaders. They "follow with deliberate willingness in adopting innovations" (*2*). The early majority, unlike the innovators and early adopters, do not utilize the weak ties outside of the institution. These individuals are very practical, waiting to see how successful others are with change. (Moore refers to this group of individuals as pragmatists.) Once these pragmatists become aware of the successes of the innovators and early adopters, they are more likely to accept the innovation due to the respect they have for their colleagues and the knowledge their colleagues will share the methods and techniques developed to implement such change in the classroom. The early majority will implement change with incremental, measurable and predictable progress, undertaking risk only with a tremendous safety net. Initial changes in pedagogy may be the addition of a different type of exercise or a change in approaching a topic. However, the implementation of the change cannot require too much time or effort and will, mostly likely, need to be accompanied by dedicated faculty development and conversation. It takes tremendous patience to convince the early majority to adopt innovative practices, along with careful pacing, investment, and talented leadership. Such endeavors are well worth it given that winning the early majority is key to any sustained change in an institution. Once the early majority adopt an innovative practice, they will be very loyal to that practice. In addition, this group of faculty will uncover the issues and necessary solutions needed to convince the late majority to adopt (*7*).

The late majority is very skeptical of innovation and will only adopt as a response to increased pressure from their peers and only when the innovation's uncertainty is removed. By the time the late majority adopt the innovation, the innovation is considered part of the system's norms. The late majority has no significant impact on the diffusion of a current innovation; however, they will have a negative impact on the diffusion of the next innovation. Assessment data, particularly data supporting acceptance of the innovation, is very important for this group as this data presents evidence for the necessity of the adoption. Laggards, perhaps more kindly referred to as traditionalists in a higher education setting, have the past as their point of reference. These individuals are very suspicious of innovations and change agents and partake in very lengthy decision making processes. Their point of reference is the past, *i.e.*, "I teach in the tradition of my discipline…" Before finally agreeing to accept an innovation, these traditionalists must have substantial evidence that the innovation will not fail (*2*). Neutralizing these individuals is not difficult. They usually help the process. Perhaps, the greatest tragedy with this group is that they, too, have something to offer in the process. They are the ones most likely to highlight the tension between the claim of the innovation and the results (*7*).

The most important group in the process of diffusing innovation is the early majority. Considerable time, effort and energy are needed with this group. Rogers' description of the energy required in this part of the adoption process brings to mind a potential energy curve with the early majority group representing the steep portion of the curve in a potential energy diagram. [Figure 4] The activation energy is equivalent to having won the early majority which then becomes the reference for the late majority.

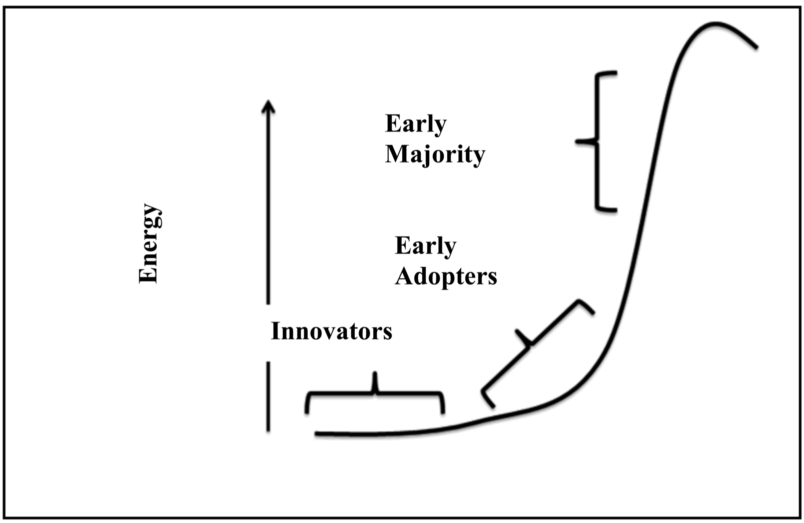


Figure 4. Energy needed to move through the Innovator group to the Early Majority group.

Even more illustrative an explanation is Moore's use of a bell curve in which the gap between the early adopters and early majority is described as "the chasm" (*7*). [Figure 5] This chasm is due to the different characteristics of the early adopters and early majority. [Table 1]

Moore's chasm represents a discontinuity in the process. Ideally, one would like to imagine the process occurring in the same manner the pendulum swings in Newton's Cradle. Newton's Cradle, a popular executive toy in the late 1960's and early 1970's, is an entertaining demonstration of Newton's Law. The cradle consists of a series of balls which swing in a pendulum motion in the same plane. Momentum is transferred through the balls when the first ball is pulled

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

away and released. If you think of the first ball as the change agent, the balls sequentially represent the innovator, early adopters, early majority, late majority, and traditionalists. (Figure 6) Ideally, the progression of change (diffusion of innovation) occurs in the same manner as the transfer of momentum from one ball to another. (Moore uses the description of Tarzan swinging through the vines.)

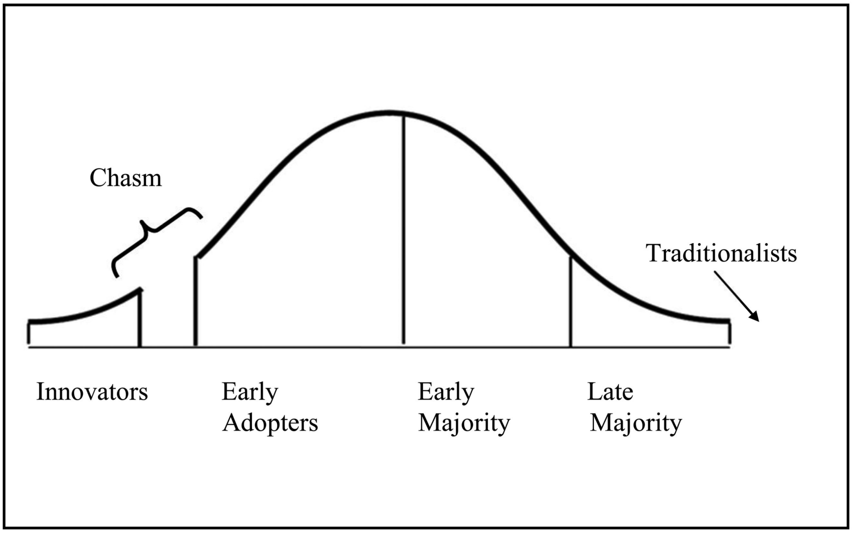


Figure 5. Moore's illustration of the chasm in the diffusion process. (Adapted with permission from reference (7). Copyright 1999 Harper Collins Publishers.)

Table 1. Characteristics of Early Adopters vs. Early Majority

Early Adopters	***Early Majority***
• More confident about position in institutional context	• Highly respectful of colleagues and cognizant of position in institution
• More in tuned and part of a national conversation	• More focused on local interests
• Ambivalent to institutional culture	• Work within institutional culture
• More visible and therefore, receive more resources	• Adoption of innovations usually occurs without support

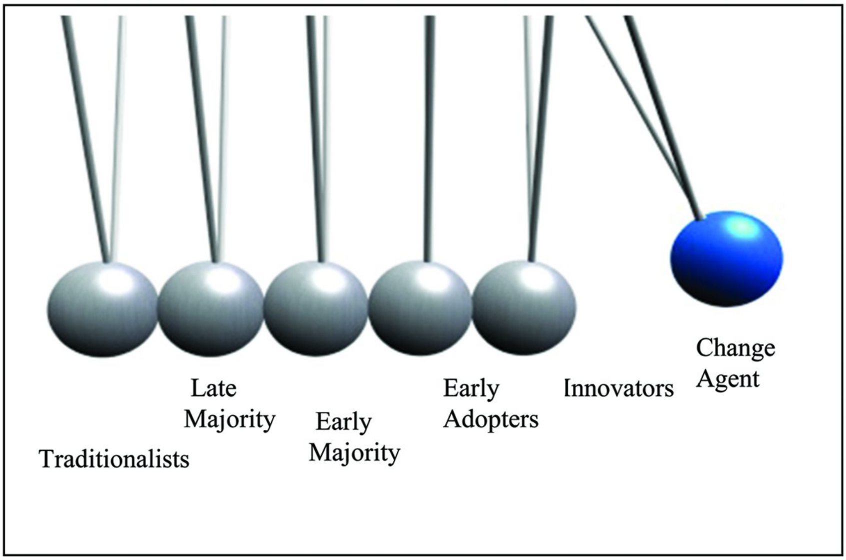


Figure 6. Continuous diffusion of innovation illustrated using Newton's Cradle. (Photo purchased from Canstockphoto.com)

Consider what would occur if a large gap existed between the early adopter and the early majority ball in Newton's Cradle. This large gap would be comparable to Tarzan reaching for a vine only to find that none is there. The process is now discontinuous, having lost the energy to continue the pendulum action. The gap which creates this discontinuous process results from the difference in communication which is needed for each group. Each group, from the innovators to the laggards, needs to have a message that "sticks" and is presented in the appropriate context.

Communication is THE most important aspect of any change leadership theory. To borrow from T.S. Elliot, "The naming of innovations is a delicate matter." Rogers continues this thought. "Words are the thought-units that structure perceptions. And of course it is the potential adopter's perceptions of an innovation that affect its rate of adoption" (*2*). This perception is further enhanced by the change vision that results from the innovation. It takes time to have a guiding coalition (the innovators, opinion leaders, and early adopters) create a change vision for the institution. Once this vision is created, we often expect everyone else to accept this vision in a fraction of the time it took to create it. Kotter provides an illustration in which he demonstrates that, usually, the change vision is only 0.58% of all communication in the institution. "So a gallon of information is quickly dumped into a river of routine communication, where it is quickly diluted, lost and forgotten" (*5*). It is no wonder then, that all four of the theories in this tapestry of change leadership emphasize the need to communicate a strong message and to deliver the message in such a way that best meets the needs of those on the receiving end.

Of the four theories in our tapestry, the one that presents a focused discussion for the creation of a strong message with effective delivery is Gladwell with his description of the Stickiness Factor and Power of Context. The stickiness factor is the quality needed for the message to stick or be successful. Such messages are inspirational and can lead to action. The message should be simple, practical advice that is irresistible and repeated often. Such messages also take advantage of metaphor, analogy, and example as suggested by Kotter. Gladwell points to the children's programs *Sesame Street* and *Blue's Clues* in his discussion of the Stickiness Factor. The same episode of *Blue's Clues* airs every day for a week. As such, every child learns that Blue's paw print is a signal that another clue is coming and overtime relates the specific clues to solving the particular problem of the day (*6*). The blue paw print was such a sticky message for my young son, that, when visiting our local zoo, he correctly interpreted the tiger paw prints painted on the path as the necessary clues in locating the Siberian tiger exhibit. The sticky messages of SENCER include "Applying the science of learning for the learning of science" and "Teaching to science through capacious, complex social issues" (*9*).

The Power of Context demonstrates the ability to influence human behavior by changing the context of the environment. Gladwell carefully illustrates this idea through his discussion of crime in New York in the 1980's and his description of the *Broken Window Theory*. James Q. Wilson and George Kelling argue that disorder leads to crime. If a broken window is not repaired, those living in that environment will assume that no one cares. Eventually, more windows will be broken and the disorder created by these broken windows will soon spread, like an epidemic, to the streets. Just like the broken windows, small, close knit groups have the ability to spread the epidemic potential of a message or idea (*6*). Those who first gathered at Santa Clara University in 2000 to launch SENCER represent one such group. Delivering sticky messages in the right social context to a small group of faculty in the early majority can have the same impact at an individual institution.

To maintain momentum and cross the chasm, the message should first be targeted to a small group of faculty, a bounded group, in the early majority that you know you can influence over time. You will need to provide a large amount of support which empowers broad based action with this group and need to have a highly specific goal that generates short-term successes and consolidates these gains to produce more change. (Kotter's Stages five, six, and seven) In addition to providing the necessary support, sticky message, and right context, this bounded group also can be influenced by creating a whole product that simplifies the change. (In fact, the whole product, in of itself, is part of the context for the innovation.) This whole product should conveniently wrap much of the support needed for the early majority into a neat, easily accessible package. Early adopters will piece together a whole product on their own while the early majority wants the whole product handed to them. Taking Moore's concept of a whole product and applying it to SENCER creates the diagram below (*7*) (Figure 7).

The center of the target represents the generic product, the SENCER ideal while the next circle out represents the expected product, normally a course. Augmented products and potential products can be represented by journal articles, wholesale change in programs, SENCER online products, accreditation, etc. The whole product can be further advanced by the connectors, mavens, and sales people who can act as translators and alter the whole product into a more simplified product as found in Figure 8 (*6*, *7*).

In this model the center of the product is the change in pedagogical approach we want to see occur which is supported by allocation of time, the allocation of resources (such as travel funds and other material which enhance the classroom experience), and the protection of a safety net in terms of promotion, tenure, and renewal.

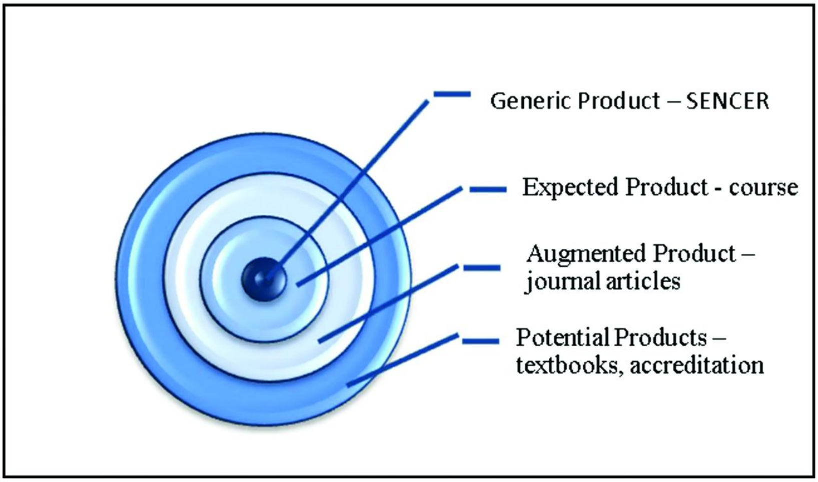


Figure 7. SENCER described using Moore's concept of the Whole Product. (Adapted with permission from reference (7). Copyright 1999 Harper Collins Publishers.)

In an attempt to empower broad-based action, Moore suggests having members of the bounded group work through an exercise in which they define a day in their life before adopting the innovation and a day in their life after adopting the innovation. Faculty may consider such aspects as the attitudes and disposition of their students, impact of attempted changes in the classroom particularly in the area of student learning and student opinion surveys, and the consequences of these actions. In considering life after adoption, faculty should consider the real requirements for implementing change, the impact of the change on the faculty member in terms of the outcomes of the change, and the rewards resulting from the change (*7*). Completing this exercise may minimize the perceived obstacles for the bounded group as well as change the structures that undermine the innovation. A discussion of the rewards resulting from the innovation may encourage risk taking and consideration of more non-traditional approaches in the classroom.

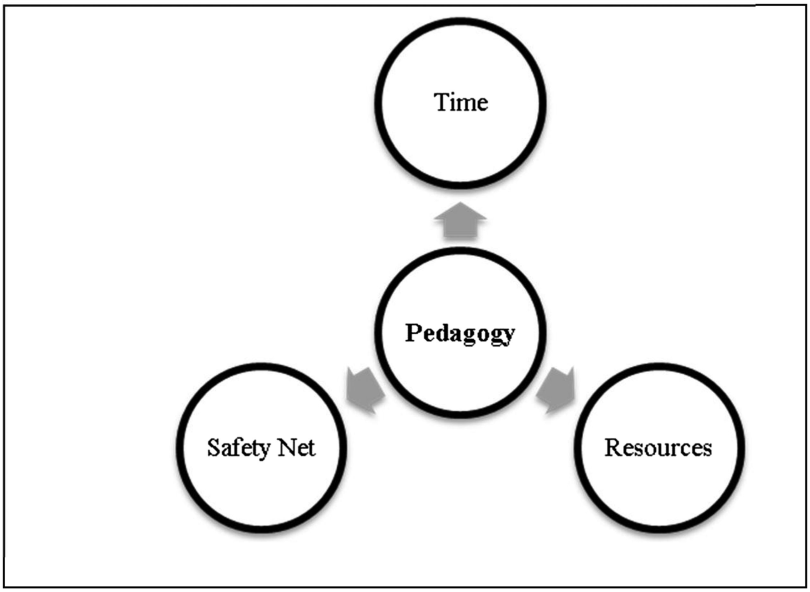


Figure 8. Simplified SENCER Whole Product. (Adapted with permission from reference (7). Copyright 1999 Harper Collins Publishers.)

Once this bounded group is on board with the innovation, the department or institution has made it to the stage of generating short-term wins. Short-term wins provide the evidence that the time and effort in adopting the change are worth it and provide the opportunity to fine-tune the vision and strategies. Moreover, the positive outcome of the innovation helps to boost the morale and provides motivation for others to become involved. The changes in students' attitudes and performance will begin to find a place in the culture. At this point, it is important for the administration to publicly recognize the individuals who helped move the innovation through to this stage, particularly those in the early majority. These short-term gains accompanied with the appropriate recognition offer the momentum to bring the late majority on board as these gains can remove the uncertainty of an innovation. Once the innovation is anchored in the culture of the institution, it is possible to bring the traditionalists on board. However, it is important to understand that as you are bringing the traditionalist on board, the innovators are probably bringing a new innovation forward.

The adoption of SENCER at SCSU has moved through the innovator group to the early adopter group. Not surprising, we were stuck trying to cross the chasm. However, our involvement at the 2012 SENCER Summer Institute (SSI) may well have pushed us over the chasm. The group of faculty that attended SSI 2012 represent SCSU's bounded group and the summer institute certainly provided the stickiest of messages and the right context to encourage a group of twelve to return to campus with three capstone courses ready for our new Liberal Education Program.

Practice

How did we arrive at the chasm? Keep in mind, none of us involved in this process had encountered any of the theories I just described when we began attempting change on our campus. However, we did have the experience of curricular revision failure to influence our approach. We were deliberate in our decision to attend the 2004 SSI. At this point, the Honors College director and I were acting in the role of innovator and change agent with SSI acting as the change agency. Our goal was to learn about this innovation and consider adopting the innovation in revising the science offerings in the Honors College. However, concurrent with our need to revise that curriculum was the NEASC (New England Association of Schools and Colleges) requirement that we revise our general education program. If we found SENCER to be compatible with our campus culture, our intent was to pilot SENCER science courses in the Honors College (a very interdisciplinary, team-taught curriculum well suited to the SENCER ideals) with the intention of using the experiences from the pilot to inform the science requirement (labeled as the Natural World requirement) in our new Liberal Education Program. Implementation of this plan was made easier given that one of the identified opinion leaders was the chair of the Gen. Ed. Task Force and a science faculty member.

Upon our return to campus in 2004, we enlisted a faculty member in our Science Education/Environmental Studies Department and a member of the Honors College faculty, to create a science course for the Honors College. This individual is well respected on campus for his command of teaching and his active research program which involves both undergraduate and graduate students. He is an ideal match for an opinion leader and best fits the description of a maven. In Spring of 2005, our first attempt at a SENCER course, "Issues in Science and Society: The Environmental Impact of Energy Use in Connecticut," was offered to a class of 18 Honors College students We were beginning our climb on the potential energy diagram as the diffusion of SENCER began to gain momentum. Our innovator, the Honors College Director, implemented the goals of our SENCER mini-grant and incorporated the new science course into the Honors College program. As the change agent, I submitted a proposal to SENCER to have a team attend the 2005 Summer Institute. This team represented the beginnings of our guiding coalition and members of this group of early adopters revised the Honors College course, changing the topic from "The Environmental Impact of Energy Use in Connecticut" to "Science on the Connecticut Coast: Investigations of an Urbanized Shoreline." This particular course is now a regular offering in the Honors College curriculum and was accepted as a SENCER model course in 2007. This course was our first short-term gain even though we had yet to create the vision and strategy, much less communicate that strategy and empower broad base action. At this point, one could surmise that we were still operating in Shakespeare's "madness" to our method. However, this model course demonstrates the necessity and importance of early adopters and the creation of a highly visible project.

At the same time we were anchoring SENCER in the Honors College, we also began transition to the Natural World requirement in the new Liberal Education program. The original description of the Natural World requirement was written by our most prominent early adopter. As chair of the Gen. Ed. Task Force, he had already been identified by the faculty as a colleague whose knowledge and expertise of curricular matters was well-respected by his peers. He formulated the purpose and experience of this area of knowledge as to be the familiarization of "students with science as a method of inquiry and to raise their awareness of the role science plays in the world. The ability to accurately and objectively articulate the scientific underpinnings of important complex issues is essential in a society that increasingly depends on science and technology" (*10*). A key element for all courses offered under this heading is "Relevance to Contemporary Societal Issues – Understanding the scientific components of some important world issues (for example, biodiversity loss, genetic engineering, global climate change, land use and planning, resource depletion, or energy concerns)" (*9*). This language validated this early adopter as the most visible opinion leader on campus. He became a connector.

The connector, maven, and other early adopters began speaking with their colleagues in the sciences, and held meetings in which the purpose and key elements of the Natural World requirement were discussed. The only concerns publicly voiced about the key elements for the Natural World requirements were the logistical and budgetary problems of requiring that all courses contain a significant laboratory component or field experience. The SENCER aspects were not questioned. Our guiding coalition had created the vision and strategy for implementation. A method to communicate this vision and to empower broad base action began to take shape.

With the Gen. Ed. Task Force chair serving as a connector for our innovation, we had someone who could help with crossing the chasm. He was in constant contact with his science colleagues, connecting the weak ties among the science departments. We were on the steep portion of our potential energy diagram and needed a concerted effort to reach the activation energy. We needed to create the sticky message, the right context, and the whole product. We began to assemble the bounded group of faculty in the early majority. Resources were made available for faculty to attend the SENCER regional meetings in Springfield, MA and the 2007 Summer Institute in Portland, ME. We even brought the 2008 regional meeting to SCSU to accommodate those individuals reluctant to travel. Additional faculty were provided resources to attend SSI 2008, 2009, and 2010. The hope was that members of the SENCER community would spread the epidemic to this faculty who would then return to campus and infect their colleagues. The summer institutes serve as the change agency as defined by Rogers, and in my role as change agent, I am linking the change agency to the faculty. [Rogers, p. 335] The best connectors for delivering the SENCER message is the faculty and alumni who attend the summer institutes.

If the department chairpersons are not innovators or early adopters, they certainly should be part of the identified bounded group of the early majority, particularly given their day-to-day interaction with their colleagues and influence with tenure-track faculty. The department chairperson, by the very nature of the position, serves as an opinion leader, and as such, can impact, either positively or negatively, the progress of the innovation's diffusion. If the department chairperson ends up falling into the late majority or traditionalist group, it will become necessary to identify another opinion leader in the department who can serve in the guiding coalition. It is best that such individuals work from a position of low risk, *i.e.*, they should, at the very least, be tenured. Untenured faculty who fall into the early adopter or early majority need support and awards from the administration to survive.

One of the science chairperson's at SCSU fell into the late majority group. Upon hearing the description of a highly regarded model course, he responded in a less than flattering manner, and no amount of persuasion could lead this individual to look at the SENCER website. As a result, his departmental colleagues rejected the innovation. However, after attending the 2007 summer institute, this same chairperson collaborated with a new faculty member to embed the SENCER ideals into two new courses which meet the Natural World course requirements. This is an excellent example of the influence provided by the opportunity to witness the innovation's impact on others and to connect with a network of weak ties.

Crossing the chasm also can be facilitated through strategic hires. New faculty will fall on either side of the dividing line in this process. They may bring traditional approaches learned from either their undergraduate or graduate education or they may be easily influenced by the opinion leaders in their department (another reason to have buy-in from the department chairperson). The dean can help in this regard by in his/her role as a change agent. The interview with the candidate provides an excellent opportunity to share the SENCER innovation. (On a few occasions, the impact of SENCER has been illustrated by the candidate initiating the discussion.) My hiring decision are influenced by the candidate's reaction to the SENCER description, and responses to questions regarding the candidate's pedagogical approach. During hiring negotiations, I reference SENCER, articulating my expectation that SENCER become part of the individual's pedagogy and offering the candidate the opportunity to attend the summer institute.

There is a cautionary note to consider when involving new tenure-track faculty in an innovative process. There must be an innovator or early adopter faculty member in the department to support the new faculty member. The dean needs to carefully monitor the reaction of more senior faculty to the innovation and skillfully guide the new hire through the political mine fields in the department. Moreover, the new faculty member needs to have the "how-to knowledge" necessary to implement SENCER successfully. If done incorrectly, the late adopters and traditionalists may not support the new hire through the renewal, tenure, and promotion process and will think they have the evidence needed to reject the innovation.

Consequently, new faculty members need to know that their efforts to bring SENCER into the curriculum will be well rewarded. I will often include comments in yearly evaluations about the positive impact such efforts have on student learning, and if need be, take others to task for devaluing such efforts. Evidence of quality in teaching is the top criterion for evaluation of faculty for renewal, promotion, and tenure. Letting faculty know that the administration notes and values their efforts in SENCERizing the curriculum and considers such efforts evidence of quality provides continued motivation to young faculty navigating the tenure process.

The dean can also proved other support come by providing reassigned time to undertake a major curricular revision and funding field trips/experiences in SENCER courses, poster presentations of class results, and invited presentations at SENCER venues. For some, moving from the traditionalist position to the late majority may be a result of wanting the same resource support received by the early adopters and early majority.

Rewarding faculty for their innovative pedagogy can motivate them to experiment with an innovation. In 2007, our first opinion leader was nominated for the J. Philip Smith Outstanding Teaching Award. Nominations come from faculty and students, and the nominee is expected to submit a portfolio demonstrating his/her innovations and quality in the classroom. There is no formal role for the dean. On occasion, nominees have requested that I write a letter of support. I normally decline, not wanting to create an atmosphere of favoritism. However, I wanted to send a message to the entire faculty in the sciences that emphasized the value I place on incorporating SENCER in our curriculum and agreed to write a letter of support. The early and late majority need the evidence that this innovation is well supported and valued before they are willing to spend time and energy revising existing courses or proposing new ones.

Each of the efforts mentioned above moved SCSU to the edge of the chasm. Yet, as Moore describes in his book, we were never able to make the final push to invade the early majority. That is, not until this past summer. Twelve faculty members, some of whom did not know each other, attended the 2012 SSI. This group represented six different departments across three schools. It was a resource intensive effort that paid off! The team leaders were among the first early adopters, each a connector in their campus faculty leadership roles. This bounded group came into contact with many weak ties and witnessed the context of SENCER on other campuses. They were infected with the SENCER ideals and are now spreading a pandemic across campus. I am optimistic that we made it across the chasm. Our next challenge is to anchor this approach in the institution culture by having the late majority and traditionalist adopt SENCER.

Some would argue that attempting to get all traditionalists on board is a waste of time. Individuals such as the one who runs his courses following the pedagogy of those who trained him probably will never engage in learning about SENCER. For the time being, his students are very happy with his courses and believe they learn a great deal. If, over time, the students begin to experience a new way of learning, their satisfaction with his course may diminish. It will be interesting to observe his response if students become dissatisfied or frustrated with his pedagogy.

The late majority and traditionalists can be forced to change. If we remove the current choice to continue teaching the traditional class by periodically reviewing the alignment of courses with the purpose and key elements of the Natural World requirement, faculty will be forced to either change the pedagogical approach of their courses or not teach in the Liberal Education Program. Such draconian measures may force faculty to become extremely late adopters. However, I would never advocate such measures and advise that careful consideration be given before taking a similar approach. Students are not well served when faculty are forced to adopt course content or pedagogies that they consider of little value.

It may be best, as David Burns has so wisely suggested, to follow the advice for facilitating change offered by the political theorist Michael Oakeshott in his essay "On Being Conservative."

> "[A] man of conservative temperament draws some appropriate conclusions. First, innovation entails certain loss and possible gain, therefore, the onus of proof, to show that the proposed change may be on the whole expected to be beneficial, rests on the would-be innovator. Secondly, he believes that the more closely the innovation resembles growth (that is, the more clearly it is intimated in and not merely imposed upon the situation) the less likely it is to result in a preponderance of loss. Thirdly, he thinks that an innovation which is in response to some specific defect, one designed to redress some specific disequilibrium, is more desirable than one that springs from a notion of generally improved condition of human circumstances, and is far more desirable than one generated by a vision of perfection. Fourthly, he favors a slow rather than a rapid pace, and pauses to observe current consequences and make appropriate adjustments. And lastly, he believes occasion to be important: and, all other things being equal, he considers the most favorable occasion for innovation to be when the projected change is most likely to be limited to what is intended and least likely to be corrupted by undesired and unmanageable consequences" (*11*). [Oakeshott]

One characteristic attributed to both the late majority and the traditionalists is a conservative nature, one in which the need for change is unrecognized. To change requires a loss of that which is comfortable and a gain of that which is anxiety ridden. The "onus of proof"" then lies with the change agent, the innovators, opinion leaders, etc. to show that the change is indeed beneficial. Such proof may come from the inclusion of assessment instruments, such as the SALG, which demonstrates the amount of learning occurring in the classroom. Scientists do understand and appreciate the value of data. If we can provide data that demonstrates the difference between the learning in a traditional course vs. the learning in a SENCER course, we may find that some traditionalists will begin to believe that SENCER is "in response to a specific defect," the decrease in scientific literacy, and that the SENCER approach "resembles growth" in his ability to increase student learning. As a consequence, this innovation is "less likely to result in a preponderance of loss" with the students' satisfaction with the course. Finally, providing faculty the opportunity to incorporate change at their own pace is advantageous. The ebb and flow of change allows the later majority and traditionalists to observe what does and does not work well in the classroom and to determine which strategies are best "limited to what is intended."

At this point in time, we offer four SENCER courses on a regular basis, two of which are model courses. Two additional courses will soon be submitted as model courses and we anticipate creation of three capstone courses for our new

Liberal Education program from the 2012 team. Among the exciting SENCER campus innovations is implementation of a concentration in Elementary Science Education for our M.S. in Science Education program in which all science content courses will incorporate SENCER. We anticipate that this degree will be very popular among elementary and middle school principles, given the recent inclusion of science on the Connecticut Mastery Test.

Teaching to science through complex, capacious social issues is not limited to the science classroom. SENCER can find a very comfortable home in critical thinking courses and first-year experience programs. SCSU developed an inquiry seminar for our entering freshmen that focuses on the role of higher education and the mission of SCSU to empower every undergraduate student with "the knowledge, skills, and perspectives essential for active participation and impassioned, ethical leadership in our rapidly changing global society" (*12*). In addition, this seminar highlights our commitment to community service, civic engagement and social responsibility and the integration of this commitment in the learning experiences of our students. SENCER courses can be readily adapted to meet the inquiry seminar's requirements, and the summer institutes are replete with examples of civic engagement and social responsibility that can be used as learning experiences for our students. It is quite possible that future SCSU teams attending the summer institutes will consist of faculty dedicated to teaching the inquiry seminar from all disciplines in the arts and sciences.

Final Reflection

A faculty member from a neighboring institution asked me "How do I convince my dean to embrace SENCER?" Another faculty member attending the 2008 institute asked what she could do to support her dean. The answer to both questions is the same – become a change agent and establish a sense of urgency. A dean or provost may not necessarily be focused on the issue of scientific learning or the status of the science courses in the general education requirement. A change agent determines the needs and recommends innovations to meet those needs. Think of the sticky message you can create by tying SENCER to such critical and immediate issues as retention, satisfactory academic progress, and time to completion. You can determine those needs through data gathered from the administration of the SALG in your own courses and your colleagues' courses. You can take advantage of the regional SENCER Centers for Innovation and request that a member of the leadership council visit your campus to meet with key administrators. The SENCER fellows are willing to assume the role of change agents and work with campus innovators to convince the early adopters, early and late majority, and even a few traditionalists to embrace SENCER. By taking into consideration the characteristics attributed to the different roles in the diffusion process, you can identify the opinion leaders among your colleagues. If possible, work to find the resources necessary to bring a team of innovators, opinion leaders, and the dean to the summer institute.

If the dean starts out as the change agent on campus, the best support you can provide is to take a strong leadership role in the process. You can lighten the workload for the dean by becoming a change agent and working to identify faculty as innovators and opinion leaders. As the change agent, you can diffuse SENCER through the curricular process by arranging SENCER meetings on campus, attending regional meetings, and proposing summer institute teams. Above all, you can begin to bring the SENCER ideals into your own teaching, so that you can point to real examples of improved learning when you are speaking with your colleagues. Your students will themselves become advocates for change.

The work of a change agent, innovator, or opinion leader can be overwhelming, particularly when the goal is to diffuse the innovation through a department or a school or a university. When it is the dean's role to be the change agent attempting to lead the school towards accomplishing the truly important, the viability of the change is dependent on the dean's ability to devote attention to the reform. Unfortunately, we deans spend our days with our attention unequally divided between the merely urgent (managing the school) and the truly important (leading the school). We are concerned with budgets, enrollments, student issues, the angry parent on the phone, and answering to our stakeholders. We constantly find ourselves putting out small brush fires created by the institution's bureaucracy and the political nature of our profession. These are the issues that keep us awake at night, the merely urgent tasks of managing the school. As a consequence, partners in the process are critical for the success of the process.

Keep in mind that deans were once faculty. We chose the academy as our profession because of our commitment to furthering and creating knowledge. We want our students to be deeply engaged in their learning, to have the highest quality education possible, to appreciate the ideals of a liberal education, and to truly be on the path of the intentional life-long learner. If we could have total control over the division of our labor, these are the issues with which we would occupy our time for these are the truly important. We need as much support and help as possible to diffuse SENCER across the school, for diffusion of SENCER focuses the faculty on these truly important issues and can eventually reach into every corner of the school. By adding your voice to this effort, we can make science education model the very best of what we know about how people learn.

Diffusion scholars recognize that adoption of an innovation is frequently accompanied by re-invention of the innovation to better match the needs of the adopter. "Potential adopters become active participants in the adoption and diffusion process, struggling to give their own unique meaning to the innovation" (*2*). I suspect that re-invention of the adopter also is a common outcome of the diffusion and that a dynamic relationship exists between the reinvention of the innovation and the adopter. I, too, have been reinvented by the SENCER innovation. During the spring of 1996, I attended a meeting with the dean of Arts & Sciences and the dean of Education. We were discussing the recent state mandate that all of our certification students be taught the use of technology in the classroom. At one point during the meeting, a very frustrated dean of Education shouted, "You people in Arts & Sciences just don't get that no one learns by being talked to." The chairperson of the Chemistry department shot back with "I beg to differ! Everyone sitting in this room learned by being talked to!" I was that chairperson, and by the spring of 1998, I was the dean of Arts & Sciences, working with the very same dean of Education to convince the

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Connecticut State Department of Education that SCSU should be reaccredited to offer initial teacher certification. I learned a great deal from that education dean, and he prepared me well for the moment when I walked into the Recital Hall at Santa Clara University and listened to José Mestre present a plenary lecture on "Using Learning Research to Transform the Way We Teach Science." I have been reminded by my colleagues in Science Education/Environmental Studies that I should not diminish my own transformation from traditionalist chemistry faculty member who believed that understanding concept and theory were all that matter in the classroom to a science educator, embracing all learning styles and attempting to engage those learning styles when I teach. José Mestre's lecture was a turning point for me. As I interacted with his pedagogy and connected that pedagogy to teaching and learning, I realized that SENCER, at its very core, is about teaching that matters, that makes a difference. I began to understand my own learning style and the learning styles of my children. I became excited about the possibility of teaching and wanted, for the first time in my career, to teach the non-science major. SENCER gave me the confidence to tackle the freshmen inquiry seminar. Instead of delivering a course from a textbook, I now know how to create a course starting with a goal. I look forward to each summer institute knowing that I will bring back to Connecticut something that can be put to use, whether it is the incorporation of some innovative use of technology in the classroom or a complex, capacious social issue as a discussion topic in the inquiry seminar. Even though I currently do not have the opportunity to teach chemistry, the diffusion of SENCER provides me with the opportunity to impact the learning of chemistry and all STEM disciplines at SCSU. SENCER has provided me a forum for discussing the teaching of science and the importance of using the science of teaching in the process.

Acknowledgments

I would like to acknowledge Karen Oates, Dean of Arts & Sciences at Wooster Polytechnic Institute for first introducing me to the work of John Kotter, Robert Sanford, Professor and Chair, Department of Environmental Sciences, University of Southern Maine for his artful assistance in weaving together theory and practice, and Ken Fredeen, Senior Product Manager, Smiths Detection, for recommending further exploration of the literature surrounding diffusion theory.

References

1. Wieman, C. *Change* (39-5), 20.
2. Rogers, E. M. *Diffusion of Innovations*, 4th ed.; The Free Press: New York, 1995; pp 34−-36, 179, 236, 252−280, 293−296, 309, 335−352.
3. Wubbels, G. G.; Girgus, J. S. In *Handbook of the Undergraduate Curriculum: A Comprehensive Guide to Purposes, Structures, Practices, and Change*; Gaff, J. G., Ratcliff, J. L., et al., Eds.; Jossey-Bass Higher and Adult Education Series; San Francisco, CA, 1997; pp 280−300.

4. Lindquist, J. In *Handbook of the Undergraduate Curriculum: A Comprehensive Guide to Purposes, Structures, Practices, and Change*; Gaff, J. G., Ratcliff, J. L., et al., Eds.; Jossey-Bass Higher and Adult Education Series; San Francisco, CA, 1997; pp 633−646.
5. Kotter, J. *Leading Change*; Harvard Business Review Press: Cambridge, MA; 1996; pp 4−14, 57, 72, 88.
6. Gladwell, M. *The Tipping Point – How Little Things Can Make a Big Difference*; Little, Brown and Company: New York, 2000; pp 2−9, 33, 54−55, 122−134, 141, 173, 198−199.
7. Moore, G. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*; Harper Collins Publishers: New York, 1999; pp 19, 33, 41−49, 54, 95−97, 109, 113.
8. Senge, P. M. *The Fifth Discipline: The Art & Practice of the Learning Organizations*; Crown Publishing: New York, 2006; pp 132, 139−-144.
9. Burns, W. D.; Kraus, D.; Riley, E. *Science Education for New Civic Engagement & Responsibilities, A Viewbook*; SENCER, NCSCE: Washington, DC, 2008.
10. Tait, J.; et al. *The Liberal Education Program at Southern: General Education Revision Proposal*, 2008. https://www.southernct.edu/development/lep/.
11. Oakeshott, M. In *Rationalism in Politics and Other Essays*; Liberty Fund: Indianapolis, IN, 1991; pp 411−412.
12. SCSU Mission Statement. http://www.southernct.edu/aboutscsu/presidentspage/mission/.

Chapter 4

How To Build a Transdisciplinary Certificate

Jeffrey B. Robb[1] and Richard D. Sheardy[*,2]

[1]Department of History and Government, Texas Woman's University, Denton, Texas 76204
[2]Department of Chemistry and Biochemistry, Texas Woman's University, Denton, Texas 76204
[*]E-mail: rsheardy@twu.edu

Certificates offer students a unique opportunity to gain knowledge and skills in a concentrated area to better prepare them for real world challenges. Herein, we describe a process for developing a transdisciplinary certificate with a civic engagement component. We conclude with two examples of certificates recently approved at Texas Woman's University.

Introduction

The changing landscape in higher education demands innovative academic programs to meet the needs of the 21st century work force. Employers are looking for students who have not only mastered the content of their discipline but who also have good critical thinking, communication and interpersonal skills. Further, students who have a broad education are often more in demand. Although traditional academic majors will provide the content depth and skill set to students, additional course work may be necessary to achieve breadth and to enhance skills. An academic minor is a proven avenue to this end but certificates provide an attractive alternative.

In this chapter, we will discuss the differences between a minor and a certificate and provide a road map for the development of a certificate. At the end of the chapter we will briefly describe two certificates recently approved at Texas Woman's University (TWU): *Science, Society and Sustainability* and *Public History*. Both of these certificates are transdisciplinary and innovative and both incorporate a civic engagement component.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Certificate or Minor

When contemplating the development of a new undergraduate academic program that is not a major, two options are available: a minor or a certificate. Both options have unique characteristics that should be considered when deciding which option to pursue. Typically, a minor is concentrated in one discipline and requires 18 credit hours, some of which must be upper division courses. Upon graduation, the minor is noted on the student's transcript but not on the diploma. On the other hand, a certificate focuses on a unifying theme that can be transdisciplinary in nature but also requires only upper division courses. Further, a capstone or practicum is often required of the student as well. Upon completion of the requirements, the student is issued a certificate. Often, certificates can stand alone without the student receiving a Baccalaureate degree or can be completed after graduation.

The choice ultimately depends upon the nature of the program, the needs of the students, and the potential costs of resources needed. Thus, in deciding which way to go, several questions must be answered: What are we trying to accomplish with this program? Is there a market for students with this training? Will students be interested in this program? Do we need to develop new courses? Do we have faculty who will participate in the program? What resources do we need for this program and how much will it cost to get the resources we currently do not have?

Undergraduate certificate programs are designed to provide additional opportunities to benefit students but are independent and distinct from regular degree programs. A program should be a coherent group of courses that meet a specific need, such as (1) training students with skills and knowledge needed for a particular work force demand, (2) providing additional education for a particular profession, or (3) teaching competencies in an emerging area of interdisciplinary study.

Steps for Developing a Transdisciplinary Certificate

1. Develop a Central Theme

The first step is to formulate the academic focal point or central theme of the certificate. One must first consider the academic programs the institution already offers and then chose a central theme that is: 1) unique for the institution; and 2) consistent with the academic mission of the institution. Being aware of national trends can play a significant role in the development of the central theme. For example, there is a lot of coverage of "sustainability" in the media, but the concept of sustainability has different meanings to different people. One of the main goals for the creation of our certificate *Science, Society and Sustainability* was to examine sustainability from different points of view. Students are often more aware of national trends than faculty and can be a valuable asset in developing ideas for a certificate. It is also very helpful to visit the web sites of other institutions to see if they have programs similar to what you want to develop and to use their programs as models.

2. Conduct Market Research

The educational goals of the certificate are to provide students with particular content and skills that potential employers are looking for. Thus, there must be a demand for such content and skills in the job marketplace. With a minimum amount of research, one can readily assess the potential market for students who have the additional content and skills gained from completion of the certificate. In planning for our certificate, we simply searched for "jobs in sustainability" on Google and www.jobsinsustainability.com was the first on this list to come up (*1*). A quick survey of the web site revealed hundreds of jobs in sustainability. For many universities, such marketing is required in the proposal for a new program of study.

3. Get Others Involved

Once the central theme has been developed, start talking to your colleagues about your ideas. In these conversations, articulate the rationale for the program, the benefits to students, some ideas about which courses should be included and the student learning outcomes. Be open minded and willing to accept ideas and criticism from others. Another very important consideration is what do the students think. Student input is a key component of the process and can be very useful in the development of the final certificate. Is the certificate something that would be of interest to them? For example, we carried out a quick assessment by a show of hands of those interested in a certificate in sustainability in our *Introduction to Environmental Chemistry* class. A survey can also be administered to students to assess their level of interest and to solicit their personal comments.

4. Develop Student Learning Outcomes

Developing feasible and measurable student learning outcomes is perhaps the most challenging aspect of the project. Meeting these objectives will enable students to develop the necessary knowledge base as well as critical thinking, problem solving and writing and speaking skills that will serve them well in their professional careers. Bloom's Taxonomy can guide you, regarding the best action verbs to use in the process (*2*).

Examples of student learning outcomes for a certificate in sustainability might include:

1. Define sustainability from scientific, sociological and economic points of view.
2. Formulate sustainable solutions to complex civic problems.
3. Assess the risks and benefits of solutions to complex civic problems.
4. Communicate potential solutions to complex civic problems to the general public and to policymakers.

5. Choose Appropriate Courses

Once the learning outcomes have been developed, find courses that can be used to attain these goals. This can be achieved by scanning the undergraduate course catalogue, picking courses that look appropriate for the certificate and examining the student learning outcomes for those courses by reading the syllabi. Some of these courses may have to be slightly modified to meet the requirements of the certificate. In some cases, new courses may have to be developed. For our sustainability certificate, we created two new courses (*3*). The first course (*Community Conversations in Sustainability*) serves as a foundation for the program and defines sustainability from different points of view. This is team taught by three faculty, one in each of the following: the Department of Chemistry and Biochemistry, the Department of History and Government, and the School of Management. This course is followed by three building block courses that provide more detail in sustainability from three different departments among the College of Arts and Sciences. These are courses that currently exist but may need to be slightly modified to incorporate sustainability in the course work. For a course to be approved as a building block for the certificate, the syllabus must include at least half of student learning outcomes for the certificate itself. Further, a committee of faculty already involved in the certificate program will review all proposed courses and syllabi. Finally, we developed a capstone course with a significant civic engagement component: *Building Sustainable Communities*. This course synthesizes student learning by having them address a sustainability issue within their community, and present their findings and solutions to the appropriate stakeholders.

6. Incorporate Civic Engagement

As practitioners of the SENCER model for improving student science learning, naturally we included a civic engagement component in our certificate as noted above. As revealed in other chapters of this book, learning is enhanced when the students become involved in civic issues of interest to them. There are numerous other examples in the literature to support this claim (*4*, *5*).

For students to relate to the University mission, they must be regarded as integral producers and sharers of knowledge and must take themselves more seriously to work hard to fulfill an important civic need. In this way, capacity for good citizenship can be encouraged and increased. Indeed, Burns states (*6*):

> *"From treating subjects in depth, [students] derive breadth of knowledge with attention to the connections to things beyond the rich but parochial gaze of a single discipline. Many… courses make opportunities for students to be directly civically engaged; others leave that entirely to the student's discretion. All stimulate intellectual engagement. In the end, they aim at a deeper form of capacity, one that employs knowledge to make our democracy (p. 8)."*

7. Develop Assessment Tools

In academia, we are hearing more and more about the importance of assessment (*7*). Thus, the viability and quality of any program is dependent upon developing assessment tools that are reasonable, rational and feasible. For each student learning outcome, a variety of tools should be considered. As indicated in Table 1 for the Student Learning Outcomes listed above, these can include traditional examinations in the courses, pre and post class surveys (e.g., SALG – Student Evaluations of Learning Gains) (*8*), written papers and/or presentations, class discussions, projects and civic engagement activities of many kinds. We note that while Table 1 offers suggested ways to assess the objectives, it is up to individual instructors to determine what works best in their courses.

Table 1. Assessment of Certificate Program Objectives

	Exams	Pre/Post surveys	Papers	Class Discussions	Projects	Civic Engagement
1. Define sustainability from scientific, sociological and economic points of view	X	X	X	X		
2. Formulate sustainable solutions to complex civic problems			X	X	X	X
3. Assess the risks and benefits of solutions to complex civic problems			X	X	X	
4. Communicate potential solutions to complex civic problems to the general public and to policymakers.			X	X	X	X

Implementation

1. Convince Your Colleagues

There are several venues you can use to convince your colleagues that the certificate is a good idea: informal hallway conversations, learning communities, faculty meetings. When we were just beginning to develop our sustainability certificate, we started by having a meeting of colleagues from around the College of Arts and Sciences. This turned into a brain storming session. We had done some preliminary research on what other universities were doing with programs in sustainability. We tailored a plan specific to our university – a plan that would ultimately benefit the students. This is a key point. In our experience, we needed

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

to convince our colleagues that this certificate will benefit the students. Another benefit for a multidisciplinary certificate is the potential to populate upper division courses with students who may not otherwise necessarily take such a course. Thus, the certificate program can generate student credit hours for departments.

Once we had a plan, we presented it first to the Dean by emphasizing the potential benefits to both students and to departments as well as the college itself. Further, our plan had minimal additional costs required for its implementation. This is another key point. Deans, as fiscal managers, are more likely to accept a plan with no significant costs and one that may actually generate student credit hours for the college. Having a supportive Dean is helpful. We then presented the plan to the other chairs in the college and noted the potential benefits to their departments (such as additional credit hours) and their students.

2. Write the Proposal

Once we had the support of our colleagues and the Dean, we set about converting our plan to a formal proposal. At TWU, such proposals are reviewed by Undergraduate Curriculum Committee. The criteria for a certificate (*9*) at TWU are listed in Table 2.

Table 2. Criteria for a Certificate at TWU

A. The certificate program must not duplicate courses required for students major and minor degree programs except in instances where certificates are granted for specialized professional preparation within a major.
B. Certificate programs should be between 12 and 18 semester hours at the 3000 or 4000 level. Exceptions will be considered on a case-by-case basis.
C. The course work comprising the certificate program must be an integrated and organized sequence of study. A project or practicum component is encouraged but not required.
D. With the exception of internship, practicum, independent projects or clinical work, all courses for certificates will be letter graded.
E. Students must maintain a minimum grade point average of 2.0 in all certificate course work. Individual programs may set higher standards for completion.
F. Students are responsible for all prerequisites specified in course requirements.
G. Course work taken as part of a certificate program may be counted toward the core curriculum at TWU.
H. Degree-granting departments can determine whether certificate courses can also count as electives toward a major or minor.

Once we were confident that our proposed certificate met these requirements, we wrote the proposal. The proposal itself had several sections:

1. *Program Description*. This is a brief description of the certificate itself and the rationale for its creation.
2. *Certificate Objectives*. What are the student learning outcomes?
3. *Who will enroll? And why?* What types of student we projected would be interested in such a program?
4. *Benefits to Students*. How are the students going to benefit from this program in terms of skills and job prospects?
5. *Program Support*. What resources are needed to implement and maintain the program?
6. *How is this program different from related majors or minors?* What is unique about the certificate that cannot be gained through more traditional means?
7. *Coursework*. What courses do the students need to complete for the certificate?
8. *Assessment*. How is the program going to be assessed?

3. Inform Students about Certificate

Once the certificate and any new courses required for the program are all approved, students must be informed. There are several avenues to inform students about the certificate, for example: 1) send an outline of the requirements to academic advisors; 2) announce the certificate in courses related to the certificate; 3) create trifold brochures with the program description that can be handed out at recruiting events and orientations; and, 4) post flyers in participating departmental offices. Once things get rolling, word of mouth by students will generate interest.

Examples of Certificates at TWU

We recently initiated two new undergraduate certificate programs at TWU. Science, Society and Sustainability was launched in the Fall of 2011 and Public History will launch in Fall 2012. Both of these programs are transdisciplinary and both have a civic engagement component. A noteworthy aspect of the Public History certificate is the opportunity for students to work with a local Informal Science Educator (ISE) such as a museum or historic site.

Science, Society, and Sustainability

The goal of the certificate in Science, Society and Sustainability is to integrate the principles and values of sustainable practices into all aspects of education and learning to enable our students to address the social, economic, legal, cultural and environmental problems facing humanity in the new millennium. Therefore, the certificate program uses a multidisciplinary approach to integrate science, society, and sustainability into a coherent program of study and civic engagement. Students completing this program enhance their academic majors by developing their ability to make thoughtful life choices and address problems from a global perspective.

Students interested in the certificate are required to take five upper division courses. As described earlier, the first foundation course is titled *Conversations in Community Sustainability* and is team taught. Students will then take three approved courses as building blocks in each of three focal areas: Natural Science and Mathematics; Arts, Humanities and Social Science; and Government and Business. Finally, the synthesis course, *Building Sustainable Communities*, serves as a capstone experience and contains a civic engagement component (*3*).

Public History

The goal of the public history certificate program is to help students bring the past to life by interpreting historical information for popular audiences in venues such as museums, archives, national and state parks, and government agencies. This is a transdisciplinary program with course offerings from history to fine arts to science. The civic engagement component of the program has students working as interns with Informal Science Educators, e.g., at a local museum or at an historic site. By using a transdisciplinary approach that integrates perspectives from history, government, and another discipline in Arts and Sciences, students will gain new and more complex understandings of history and its public presentation, enhance their major course of study by broadening intellectual vantage points, and possibly explore new career opportunities.

Students interested in this certificate are required to complete 13 to 16 hours of coursework consisting of:

1). A 3-hour “gateway” history course, Introduction to Public History
2) A 3-hour history elective (from classes such as Oral History, History of the National Parks, Museum Management, Everyday Life in Colonial America, etc.);
3) A 3-hour elective from another discipline in Arts and Sciences such as drama, art, English, fashion and textiles, or science (e.g., The Theater and Drama, Art History, History of Costume, Survey of American Literature, History of Science);
4) A 3-6 hour internship at a local museum, historic site, preservation/ conservation agency, etc.; and
5) A 1-hour capstone project in which students develop and defend a portfolio and presentation applying what they have learned in their course work to their internship(s).

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Conclusions

Transdisciplinary certificates can promote student learning in new and exciting ways, encourage students to explore potential careers in the inherently transdisciplinary fields, and provide credentials that validates student achievement. These programs can broaden the knowledge base for the students and, at the same time, enhance their critical thinking, communication and interpersonal skills. Given the limitations of creating new majors or minors and the greater flexibility that a certificate can provide, such a program can be a viable option for universities and a valuable learning experience for students.

References

1. Job Sustainability. http://www.jobsinsustainability.com.
2. Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H.; Krathwohl, D. R. *Taxonomy of Educational Objectives, Handbook I: Cognitive Domain*; Bloom, B. S., Ed.; Longman: White Plains, NY, 1956.
3. Maguire, C.; Jones, R.; da Rosa, J.; Sheardy, R. D. Science, Society and Sustainability: A Certificate Program. In *Sustainability in the Chemical Curriculum*; Middlecamp, C., Jorgenson, A.; ACS Symposium Books 1087; American Chemical Society, Washington, DC, 2012; pp 129−138.
4. Burns, W. D. Knowledge to make our democracy. *Liberal Educ.* **2002**, *88* (4), 20–27.
5. Eyler, J.; Giles, D. E.; Stenson, C.; Gray, C. *At a Glance: What We Know about the Effects of Service-Learning on College Students, Faculty, Institutions and Communities, 1993−2000*, 3rd ed.; Vanderbilt University: Nashville, TN, 2001.
6. Ash, S. L.; Clayton, P. H.; Atkinson, M. P. Integrating reflection and assessment to capture and improve student learning. *Michigan J. Community Service Learn.* **2005**, *11* (2), 49–60.
7. Walvoord, B. E. *Assessment Clear and Simple: A Practical Guide for Institutions, Departments, and General Education*, 2nd ed.; Jossey-Bass: San Francisco, 2010.
8. Student Assessment of Their Learning Gains. http://www.salgsite.org.
9. TWU Undergraduate Certification Programs: Policy Guidelines. http://www.twu.edu/downloads/undergrad-services/CertificateGuidelines_UndergraduateRevised.pdf.

Chapter 5

Teaching and Learning on Radioactive Landscapes: Nuclear Unclear

Cathy Middlecamp*

Nelson Institute for Environmental Studies, University of Wisconsin-Madison, Madison, Wisconsin 53706, United States
***E-mail: chmiddle@wisc.edu.**

This paper discusses issues of teaching and learning on nuclear landscapes, that is, places in time and space where people have come into contact with radioactive substances. For over 15 years, the author has taken up vantage points on different nuclear landscapes, ones that are rich not only with nuclear facts and concepts but also with intriguing stories. In the process of navigating these landscapes, her students have sent the message that "nuclear is unclear," that is, the relevant facts and concepts have surprising complexity. Furthermore, her students have made it clear that because they (and all humans) cannot directly detect nuclear radiation, people today and throughout history have been unaware of the hazards of nuclear radiation until it was too late. More generally, this paper points out that when teaching any course that engages students with real-world issues, it is important to give attention to the complexities inherent in the scientific content that can complicate the teaching and learning processes.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Introduction

My mother of 93 years isn't much interested in the finer points of interior decoration. So it surprised me one day when she commented on the carpet outside of her assisted living apartment.

"Look at this carpet. It is really blah," she informed me.

The carpet in question was grey with a repeating pattern, spotless, and had a darker gray border as an accent. It seemed attractive and was well matched to its surroundings.

"It looks OK to me, Mom." I replied, after making my assessment.

Mom held her peace and we moved on to other topics. A month later, however, the conversation picked up right where we had left off.

"Look at this carpet. It has no personality at all. I don't understand why folks here ever decided to install it."

Once again, it was uncharacteristic of my mother to talk about carpet, furniture, wall colors or *anything* related to interior decor. So she had my attention. I looked down at the carpet. Once again, I concluded that it harmonized nicely with the hallways, neither gaudy nor worn.

Then it hit me. My mother moves through the hallways of her nursing home using a walker, bent over as she takes each step. With her eyes pointing downward, *all that she can see is the carpet*. From her vantage point, the carpet really is boring. No personality.

In contrast, she is quite fond of the red and green carpet that is in another part of the nursing home. Brightly colored with a bold design, this somewhat gaudy carpet has "personality." Finally, I understood what she was trying to tell me.

Only after the episode with my mother did I come to understand a point made by one of my chemistry colleagues. By chance we had met in the hallway and got to conversing about introductory chemistry courses. He remarked to me, "I don't see why you teach so much nuclear chemistry. For the most part, I find that teaching nuclear chemistry is boring."

BORING…? As far as I was concerned, few things were more fascinating than the stories of nuclear science that began at interface between people and the radioactive substances. As my colleague knew, I had been co-teaching with a colleague a course called "Uranium and American Indians," a 2004 SENCER model course, and the first chemistry course in my university system to meet the state-wide ethnic studies requirement (*1*). Among students and faculty alike, it had created a buzz (*2*).

For years, I also taught another SENCER course on people and radioactive substances that was nicknamed "The Radium Girls and The Firecracker Boys (*3*)." The former were the women who painted radioactive glow-in-the-dark watch dials, in the process ingesting lethal amounts of radium (*4–6*). The latter were the Cold War nuclear physicists who proposed using thermonuclear devices to blast out a harbor on the land of Native Alaskan peoples (*7*).

In contrast, my chemistry colleague taught a unit of nuclear chemistry as part of the general chemistry curriculum. He persisted in his line of thought.

"I just don't find that teaching about alpha, beta, and gamma decay is of much interest."

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Suddenly, the parallel with my mother's carpet struck me. If you have your head down in a chemistry textbook, you are likely to see an endless string of questions on alpha, beta, and gamma decays, each one with a set of little numbers to keep track of. Doing half-life problems may be equally tedious, and the same could be said for the calculations for binding energy. My colleague was right. Such types of problems were boring both to teach and to learn.

The bottom line? You see what you are looking at. So unless otherwise constrained (as my mother was), it makes sense to pick a vantage point that offers the most interesting view possible.

SENCER – Courses with a View

Consider the experience of positioning yourself at a point where a real-world issue is squarely in view. Perhaps this occurs as you read a popular press article on the recent air quality in downtown Houston. Or perhaps it happens as you watch a documentary on coal production in Montana. Or perhaps having the opportunity to hear the oral histories and songs of the caribou herders in Norway perks your interest about the radioactive fallout from Chernobyl.

No real-world issue will engage all learners; then again, such an issue is unlikely to bore anybody either. As my mother might point out, real-world issues have "personality" are not "blah." Characteristics such as these make you glad that your head is up and that your eyes are able to scan the terrain.

Through well over a decade of work, the SENCER project, Science Education for New Civic Engagements and Responsibilities, has acquired a track record in creating courses "with a view (*8*)." These courses enable students to learn science through big, contested, and complex issues that matter to communities of people on the planet. Thus at its heart, SENCER is about finding vantage points that engage our students in learning by placing a real-world issue is squarely in their view.

The "SENCER Ideals" inform how we select vantage points for our students (and ourselves) (*9*). Two are particularly relevant to this discussion:

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

These ideals also remind us that knowledge is needed to navigate the terrain. This knowledge isn't a collection of facts and concepts that possibly might be relevant. Rather, it is practical; that is, what one needs to know right now in order to understand the issues.

Views on the Nuclear Landscape

Nuclear landscapes offer many possible views. Look in one direction and you will see a nuclear power plant, perhaps Chernobyl, Three Mile Island, or Fukushima Daiichi. Less familiar nuclear reactors include the British one at Windscale that caught on fire (1957), SL-1, a Cold War Idaho research reactor with fatalities (1961), and K-19, a nuclear-powered a Soviet submarine, also with fatalities (1961) (*10*). Also on the landscape are the many nuclear power plants that reliably have provided electricity for decades. Excellent resources exist to help chemistry instructors understand the nuclear terrain, including the nuclear fuel cycle (*11–13*).

Look another direction and you will see the legacy of the Cold War. For example, people living on the Marshall Islands today still deal with the aftermath of nuclear testing in the 1950s; the same is true for indigenous people in Australia. In the former Soviet Union, look for views of the city of Mayak and its nuclear reactors that once bred weapons-grade plutonium. In the United States, soldiers, plant workers, scientists, and their families at Hanford, Oak Ridge, and Los Alamos national laboratories can tell stories of early atomic history. The significance of their stories is made clear by these words that instruct readers at a nuclear digital library:

> *"Beginning with the Manhattan Project, the massive scientific and technological effort that produced the first atomic bombs, nuclear issues have had a profound effect on every aspect of society. Those issues have influenced the evolution of science and technology, domestic politics and international relations in many countries, as well as the arts and humanities (14)."*

And look still in another direction and you will see people who worked in the uranium mines, their workplaces showing the characteristic yellow tinge of uranium oxides, and their homes contaminated with the yellow dust. In the United States, the most familiar may be the Navajo (Dineh) uranium miners on the Colorado Plateau (*15–17*). Look also to the stories of miners in Australia, Canada, and Africa. The issues persist on these nuclear landscapes, because the questions of whether to mine, and if so, how to mine persist from generation to the next.

Finally, find the unique markers on the nuclear landscape that lasted only briefly but nonetheless had far-reaching consequences. One example is the radium dial painting industry of the 1920s. Equipped with pots of luminous paint, women painted the hands of watches, clocks, dials for military vehicles and aircraft, and glow-in-the-dark trinkets. The women worked quickly to earn good pay, pointing their fine brushes with their lips. At the same time, they ingested enough radium to kill them (*18*).

These vantage points on the nuclear landscape all have something in common – a story. These stories involve one or more radioactive substances, such as uranium, radium, plutonium, iodine-131, and strontium-90. These stories also involve people, that is, miners, nuclear industry workers, military officers, local community members, politicians, and concerned citizens. Radioactive substances and people *both* play key roles in the stories.

Over the past 15 years, I've positioned my students in nuclear landscapes that hold stories. As mentioned in the previous section, I've taught two courses based on the SENCER ideals. One was "Uranium and American Indians," co-taught in the Chemistry Department with a Navajo colleague, Omie Baldwin. A second was "Radioactivity, People, and the Planet" that I currently am teaching in the Integrated Liberal Studies Program. More recently, I also taught a version of this course as a capstone for students in the Nelson Institute for Environmental Studies. All courses carry three credits and with enrollments of about 20 students. With the exception of the capstone, all of these courses were intended for a general audience with no physical or biological science prerequisites.

No matter which course I am teaching, my students almost immediately indicate that concepts such as *radiation* and *radioactivity* are confusing. So although nuclear landscapes hold intriguing stories, they nonetheless may be full of conceptual potholes.

With my students as my teachers, I finally came to realize the severity of these potholes. For 20 years prior to teaching these SENCER courses, I had "covered" nuclear chemistry in a unit as part of the first-year general chemistry curriculum. As evidenced by student course evaluations, I did a fine job of engaging students in the content, assessing their ability to explain things and work problems, and connecting what they learned to bigger issues such as nuclear power. But until I began to spend time with students exploring these same concepts on broader nuclear landscapes, I had no idea how difficult these concepts actually were. Indeed, "nuclear" could be "unclear."

Nuclear Facts and Concepts

Once you launch a course with a "nuclear view," your students are poised to explore the surrounding terrain. To do this, they need to know the nuclear facts and concepts that will guide their feet on the landscape.

For the purposes of this discussion, *facts* will be taken as "bite-sized chunks" of information that must be memorized and not figured out. For example, it is a fact that radon is a radioactive gas that occurs naturally. Another fact is that both Sr-90 and Cs-137 have half-lives of approximately 30 years. In contrast, nuclear fission is a *concept*. Like all concepts, it has a definition (or possibly several) that is the starting point of a much longer discussion including which nuclei split, under what conditions, what happens when they do, and how to represent the process symbolically (*19*).

When positioned on any nuclear landscape, consider these possibilities for a "starter set" of facts about radioactive substances on our planet:

- Some radioactive substances occur naturally on our planet. Most occur in low concentrations.
- Other radioactive substances exist on our planet because they have been produced by humans.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

- With our senses alone, we are unable to detect the radiation from any of these radioactive substances, either natural or human-made.
- Most of the substances on our planet (and in our bodies) are *not* radioactive.
- Under some circumstances, radioactive substances are harmful to people.
- Under some circumstances, radioactive substances can be used to heal people.

Clearly other choices are possible. The number of these facts – and which particular ones – depends on the context of interest. For example, if the context is nuclear waste or nuclear fallout, facts about specific fission products such as Sr-90, I-131, and Cs-137 are necessary. In contrast, if the context is nuclear medicine, facts about technetium, I-131, and Co-60 may be necessary. Both contexts require facts about the biological effects of ionizing radiation.

In order to successfully traverse a nuclear landscape, students also need to understand *concepts*. For example, the concept of a *radioactive substance* was employed in the previous list of nuclear facts (*20*). Depending on the audience, other nuclear concepts might include:

- Radiation, including nuclear, electromagnetic, and ionizing
- Atoms and their nuclei, protons and neutrons
- Isotope, both stable and radioactive
- Nuclear decay processes (alpha, beta, gamma)
- Half-life
- Nuclear fission, nuclear fusion
- Effective dose (units of rem & sievert)

To illustrate how nuclear concepts can be "unclear," the next section explores two such concepts, *radioactive substances* and *radiation*. They not only are inherently confusing in their own right but also are confused with each other, including in the popular press.

Class Conversations about Radioactive Substances

Beginnings are important. On the first day of class, after the customary words of welcome to my new students, I launch a conversation about the radioactive substances present in my classroom. It goes something like this.

"This room contains some substances that are radioactive. Where do you think they are?"

In order to encourage my students to venture an answer or two, I then get out my hand-held Geiger counter, turn it on, and bring it near the orange Fiesta Ware plate that I have placed where all can see it. The Geiger counter responds immediately with its characteristic beeps.

"OK," I say, leading my students to continue their inquiry. "This plate is radioactive and we'll talk more about it soon. What else in the room is radioactive? I can use the Geiger counter to check out anything you like."

The answers given by my students largely depend on their prior knowledge and occasionally on their use of cell phones. Either they already know that trace amounts of (1) radon are in the air, (2) carbon-14 and potassium-40 are in our bodies, and (3) uranium and its decay products are in many stone building materials … or they don't. They either recognize that clear green glass plates that I placed on the front desk are colored with uranium oxide … or they don't. And they either recently have had a medical diagnostic test that uses a radioisotope such as I-131 … or they haven't.

The absence of any real knowledge seems to be no impediment to a lively classroom discussion. Students suspect the presence of radioactive substances almost everywhere! And indeed this indeed is the case if one considers a radioactive nucleus here or there. But this level of detail usually is not relevant to the conversation at hand – we are in search of amounts we can measure with my Geiger counter.

In order first to have students each commit to an answer of their own (assuring them that these will not be graded), I hand out the data sheet reproduced in Table 1 and collect their responses. Next, I have students form small groups in which they fill out the same sheet again, discussing each entry in turn.

Table 1. Class Activity Sheet (What in this room is radioactive?)

	not radioactive	*slightly radioactive*	*moderately radioactive*	*Rationale*
Your choice:				
Your choice:				
Your choice:				
The walls				
The floor				
The air				
The lights				
The chairs/desks				
Laptop computer screens				
The electrical outlets				
The human beings				
The Geiger counter				

Composite data for the lights, laptops, electrical outlets, and the Geiger counter are shown in Table 2. According to the majority of my students, all of these are slightly or moderately radioactive, even the electrical outlets! Admittedly I chuckle to myself at some of these responses; for example, I am particularly fond of "it takes one to know one" as a reason why the Geiger counter is radioactive.

If the joke is on anybody, though, it is on me. For many of the years that I taught nuclear chemistry, I had no idea that my students thought that the fluorescent lights were radioactive. Similarly, I did not recognize how confusing the term *radiation* was; that is, the confusion inherent between electromagnetic radiation and nuclear radiation. More about this confusion follows in the next section.

There is good reason for the responses that not only my students give to the question of what is radioactive or not, but also that people *in general* give. I have done this same activity with many audiences, including graduate students, parents, and high school teachers. These groups suspect, just as do my students, that cell phones, computer screens, and overhead lights are radioactive. Why might this be the case?

One reason is that we humans lack the ability to detect nuclear radiation with our senses. In order to know whether or not a radioisotope is present, we need an external device such as a Geiger counter or film badge. In the absence of detectors such as these, and lacking prior knowledge about where radioisotopes are likely to be found, all we can do is to make our best guess. Given this reality, part of the opening conversation with my students goes something like this.

"Folks, you all are great detectors of heat. You can feel it on your skin. Likewise, with your eyes, you are great detectors of light (*21*). But with nuclear radiation? Sorry, you are a lousy detector. Take no offense, so am I. In fact, so is everybody."

Indeed, we are "blind" to alpha particles, beta particles, gamma rays, and even X-rays. We are unaware of the cosmic rays that are passing through our bodies every second. Although we can make a list of radioactive substances present in the room (tiny amounts of them), this list isn't something that we can directly perceive. Each item on the list, e.g., the radon in the air, the uranium in stone building materials, and the trace amounts of C-14 and K-40 in our bodies, relates to facts that my students will learn over the course of the semester.

To put this in a broader perspective, *history would have taken a very different course had we as humans been able to detect the presence radioactive substances*. This bit of knowledge is essential to know in traversing nuclear landscapes. Consider, for example, the cleanup after the accidents at Fukushima Daiichi and Chernobyl nuclear power plants. Also consider the spread of radioisotopes from atmospheric weapons testing in the 1950s. People would not have had to depend on experts if they could have seen for themselves the spread of the radioisotopes. Similarly, the history of mining communities would have taken a different course had the workers been able to detect the presence of uranium, radium, radon and plutonium in their workplaces, on their clothing, and perhaps even in their homes.

Table 2. Student Responses to Class Activity (What in this room is radioactive?)*

	not radioactive	*slightly radioactive*	*moderately radioactive*	*Rationale*
Lights	10	48	14	- The electric current to the light produces radioactivity. - Maybe fluorescent things are partially radioactive? - The word fluorescent is associated with radioactivity. - Why not? They produce light. - They glow like radioactivity does. - Radiate light. - They glow … I'm not sure why really.
Laptop computer screens	13	43	15	- Lets off a glow/energy/heat - Perhaps a little radioactivity helps keep screen lit with power supply. - Seems like some components could be radioactive. - Same rationale as lights. (i.e., not sure, I just feel like it does.)
Electrical outlets	31	29	11	- Probably only radioactive if nuclear power was used. - Metal in wires may be radioactive - If you stick your finger in it -- pretty radioactive. - Seems like of all the items, this would be the one.
Geiger counter	25	30	11	- Might have to be radioactive to find radioactivity. - In order to detect radioactivity, it may have to contain some radioactive elements. - Takes one to know one?

* Data from four undergraduate courses taught in 2009-2012 (n = 72). Students left some questions blank.

We humans are lousy detectors of nuclear radiation. As it turns out, we aren't all that good in speaking and writing about radioactive substances either. The next section delves into another set of reasons why nuclear can be equated with unclear, at least as far as my students are concerned (*22*).

Class Conversations about Radiation

Once the conversation about radioactive substances in our world is launched, a second conversation rapidly ensues. The students initiate it with their comments about fluorescent lights and laptop screens. They point out that these radiate light and "glow" and thus emit nuclear radiation.

Once an instructor opens the door to nuclear radiation, other types of radiation tumble through as well. In part, the problem lies in our use of the word *radiation*. Consider, for example, the billboard pictured in Figure 1. The text it contains refers to the electromagnetic radiation emitted by the Sun; namely, ultraviolet light.

Figure 1. Billboard for Madison Area Technical College.

All radiation isn't created equal! Compare the radiation emitted by fission products of a nuclear reactor with the types emitted by an incandescent light bulb. The former is *nuclear radiation*, that is, alpha particles, beta particles and gamma rays. In contrast, the latter are types of *electromagnetic radiation*; namely, visible light and infrared radiation (heat).

Furthermore, some nuclear professionals employ a third term, *ionizing radiation*. This refers to any type of radiation, nuclear or electromagnetic, with an energy that is high enough to leave a trail of ions in its wake. Alpha particles are a type of ionizing radiation. So are beta particles and gamma rays. So are X-rays, a high-energy type of electromagnetic radiation. To add to the confusion, X-rays and gamma rays are two different names for the same thing.

These three terms used to categorize radiation – nuclear, electromagnetic, and ionizing – use different categorization schemes. Ionizing radiation is defined by how it interacts with matter; that is, it produces ions. Nuclear radiation, a subset of ionizing radiation, is defined by its origin, that is, the nucleus of an atom. In contrast, electromagnetic radiation is defined by its frequency and wavelength. Rather than saying ionizing, nuclear, or electromagnetic, people tend to say "radiation" and leave it to the listener to figure out the type by the context.

Given this, it is small wonder that people are confused about what is radioactive and what is not. Not only are people lousy detectors of nuclear radiation, but also they are lousy at clearlystating which type radiation they are talking about. Thus, it makes sense that people think that computer screens, fluorescent lights, and cell phones all are radioactive. Indeed, they all emit radiation.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Once the conversation about radiation begins in my class, I have my students work on several class activities in rapid succession. The first one gives them practice in using the context to recognize the types of radiation intended by the speaker (see Table 3), nuclear or electromagnetic (*23*). The second activity, not included here, gives students practice in writing sentences that contain the word *radiation*. By the context, they are instructed to be referring either to *nuclear radiation* or to *electromagnetic radiation*. After doing this individually, they then critique each other's work in small groups or write the sentences on the board for all to discuss. Following these activities, students are assessed in their ability to use and understand the term *radiation* on quizzes, in their papers, and in class presentations. Table 4 shows typical quiz questions.

Even having practiced using activities such as these, the confusion persists in the minds of my students. Midway into the semester, one student provided a particularly salient example of this confusion which she wrote about the "radioactive radiation" that was the likely cause of Marie Curie's death. Perhaps she was onto something with her choice of words.

Table 3. Class Activity Sheet: Radiation vs. Radiation (*24*)

Read this passage. Is the writer referring to *nuclear* radiation or to *electromagnetic* radiation? Circle the former (nuclear radiation) and mark the latter with a star (electromagnetic radiation).

"Spiderman leaned up against the stone blocks of the Chrysler building. The radiation emitted by the sun had warmed these blocks earlier in the day, and their warmth strengthened him as he pondered his new information.

Earlier, he had entered this building quietly. He had quickly found the room he was looking for by the green glow of the many computer terminals it contained. He sat down at one of the terminals, logging on while bathed in its green radiation.

He began digging for the information he needed. Yes! Right there on the screen were the plans for shipping the waste from the nuclear power plant by train. The villain Dr. Octopus was tracking it. The waste in one train car alone would give off enough radiation to sicken an entire town. Was that what Dr. Octopus was planning . . . ?

As he dug further into the computer data base to learn more, the office lights suddenly blinked on. The radiation emitted by the lights momentarily blinded him, but he had enough warning to swing out of a window before (he hoped) being seen. His spider-senses told him that there was a crowd on its way. He was thankful again for the radiation from the spider venom that changed his DNA – his powers again saved him. Later, he would have to go back to find what Dr. Octopus was planning with the radioactive waste."

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Table 4. Sample Quiz Questions on Radiation/Radioactivity

1. Please write a single question (not two!) that demonstrates you know enough to ask a good question. Then provide a clear answer of 3-4 sentences. The topic of the question must relate to *radioactivity* and/or *nuclear radiation*. In addition, your question must relate to something that was confusing you that you wanted to straighten it out. Your answer will be assessed on two points: (1) how well your question pinpointed a confusing issue, and (2) how clearly your answer demonstrated that you had figured it out.
2. Most people have heard the term "radiation", but do not know the specifics. From what you have learned so far, what do you think people should know? Make a list of 6-10 "talking points" that you would use to convey the specifics to the general public.
3. When people refer to "radiation," sometimes they mean nuclear radiation and other times they mean electromagnetic radiation. Write 2 sentences that use the word radiation. By the context, the meaning should be clear to the reader as to which type. Your answer will be assessed on spelling and grammar in addition to its intellectual content.
Sentence #1 (context = nuclear radiation)
Sentence #2 (context = electromagnetic radiation)
Note: Question #1 was announced to students prior to the quiz but not practiced. Questions #2 and #3 were practiced in class.

The difficulties my students experience are not unique. Many others also experience difficulty speaking and writing with the term *radiation*. For example, consider this line from a newspaper article about the Fukushima Daiichi nuclear power plant.

> "With no guidance from Tokyo Electric Power Company, the nuclear plant's owner, or the central government, town officials led evacuees north, believing winds were blowing the radiation south (*25*)."

As a point of clarification, nuclear radiation is not a physical substance like volcanic ash that can be carried by wind. Rather, the atoms and molecules of radioactive substances can be transported widely, both by air and water.

As another example, recall recent news stories about how radiation is "leaking" from something or other. Again, radiation is not a substance like water that can seep through or around physical barriers. Instead, the writer should be referring to the radioactive substances – better yet by name – that can be transported in this manner. Examples such as these together with several others have helped me to realize the complexities inherent in the concepts of *radiation* and *radioactive substances* (*26*).

Lessons Learned

With good reason, all instructors will not choose to position their students on nuclear landscapes. In fact, chemistry instructors, faced with tough choices on what they believe they can "cover" in general chemistry, have looked for topics that they can cut. Nuclear chemistry is one of the candidates A 2011 article in *Chemical and Engineering News*, the weekly magazine of the American Chemical Society, underscored this sentiment: *"Feedback from college faculty also led the curriculum development committee to eliminate nuclear chemistry (27)."*

Even so, the lessons learned from teaching on nuclear landscapes are relevant to others. Just as we hope our students can transfer what they learned in one context to another, we hope that we can do the same as their instructors. As one possibility, consider how what is learned on nuclear landscapes may transfer to those on which electricity is generated, transmitted, and used. The concepts of *energy*, *power*, and *electricity* are every bit confusing as those of *radiation* and *radioactive*. This confusion only deepens when students work with the units of kilowatts and kilowatt-hours. Just nuclear radiation is "invisible," so is electricity. We need the help of a Geiger counter to detect nuclear radiation; similarly, we need the help of a watt meter to perceive the amounts of electricity that our appliances are using.

Here is a more general list of ideas that might be useful to those teaching from vantage points on any other real-world landscapes.

1. The concepts that we teach in general chemistry, when placed in context of a real-world issue, take on a startling breadth and depth. Students rightly experience difficulty as they attempt to apply these concepts.
2. When learning a topic in the context of a real-world issue, students may quickly reveal what they understand (and don't) once they attempt to use these concepts as they read, speak, write, or to listen to others (*28*).
3. Once instructors better come to recognize what their students don't understand, they can design activities to help students build a better understanding of these concepts. Tables 2 and 3 offer material that can be generalized to other areas of inquiry.
4. Instructors, when placed on a real-world landscape, will build their own knowledge as well, sometimes in ways surprising even to those well-seasoned in the classroom.

When positioned on any intellectual terrain, we and our students see what is in our view. So unless otherwise constrained, it makes sense for instructors to pick a vantage points that offers interesting the most interesting views possible. Nuclear unclear! Those who quip "it is all about the journey" have got it right.

Acknowledgments

This paper is derived from a plenary address at the 2011 SENCER Summer Institute, Butler University, Indianapolis, Indiana. The author gratefully acknowledges the intellectual contributions, collegial support, and good cheer of all those who have contributed to the SENCER project, especially Wm. David Burns and Karen Oates (PIs), Jay Labov (National Research Council) who was co-presenter of the *Nuclear Unclear* plenary address at the 2011 SENCER Summer Institute, and Richard Sheardy (SENCER Southwest Regional Center director) who, as editor of this volume, ensured that I brought this submission to the finish line. Equally important are the undergraduate students at the University of Wisconsin-Madison, past and present, who have been my teachers in so many ways. They continue to encourage me in my attempts to explore new nuclear landscapes. This past semester, the words of one student in the final course evaluation meant the world to me: "*She integrated a perfect balance of scientific concepts with the overarching theme that these concepts truly affect our history and shared human experience.*"

References

1. Middlecamp, C. H.; Bentley, A. K.; Phillips, M.; Baldwin, O. Chemistry, society and civic engagement. Part II: Environmental chemistry & ethnicity. *J. Chem. Educ.* **2006**, *83*, 1308–1312.
2. Carlson, E. Course Blends Chemistry, American Indian Studies. *Wisconsin Week*, December 11, 2002.
3. Middlecamp, C. Integrated Liberal Studies 251, "The Radium Girls and the Firecracker Boys". Three credits, for non-science majors. http://www.chem.wisc.edu/middlecamp/251-Spring12/ (accessed June 2012).
4. Clark, C. *Radium Girls: Women and Industrial Health Reform*; Chapel Hill: University of North Carolina Press, 1997.
5. Mullner, R. *Deadly Glow: The Radium Dial Painters Tragedy*; American Public Health Association, 1999.
6. Harvie, D. I. *Deadly Sunshine: The History and Fatal Legacy of Radium*; Tempus Publishing Limited: Gloucestershire, U.K., 2005.
7. O'Neill, D. *The Firecracker Boys, H-bombs, Inupiat Eskimos, and the Roots of the Environmental Movement*; Basic Books, 2007.
8. Science Education for New Civic Engagements and Responsibilities. http://www.sencer.net/ (accessed June 2012).
9. The SENCER Ideals illustrate the principles and philosophies that guide SENCER's approach to educational practice. http://www.sencer.net/About/sencerideals.cfm (accessed June 2012).
10. The stories of Windscale, K-19, and SL-1 all can be found on the Internet. As a starting point, Wikipedia offers articles on each one.
11. Settle, F. A. Uranium to electricity: The chemistry of the nuclear fuel cycle. *J. Chem. Educ.* **2009**, *86*, 316–323.

12. Zevos, N. Radioactivity, radiation, and the chemistry of nuclear waste. *J. Chem. Educ.* **2002**, *79*, 692–696.
13. The Living Textbook of Nuclear Chemistry. http://livingtextbook.oregonstate.edu/ (accessed June 2012).
14. ALSOS, Digital Library for Nuclear Issue. http://alsos.wlu.edu/about.aspx/ (accessed June 2012).
15. Eichstaedt, P. H. *If You Poison Us: Uranium and Native Americans*; Red Crane Books: Santa Fe, NM, 1994.
16. Brugge, D., Benally, T., Yazzie-Lewis, E., Eds.; *The Navajo People and Uranium Mining*; University of New Mexico Press: Albuquerque, NM, 2006.
17. Pasternak, J. *Yellow Dirt: An American Story of a Poisoned Land and a People Betrayed*; Simon & Schuster, 2010.
18. See references 4, 5, and 6.
19. Here is a symbolic representation of nuclear fission: $^{1}_{0}n + ^{235}_{92}U \longrightarrow [^{236}_{92}U] \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$ In contrast, this does not represent nuclear fission (it is alpha decay): $^{238}_{92}U \longrightarrow ^{234}_{90}Th + ^{4}_{2}He$.
20. Other terms may be substituted for *radioactive substance*. These include *radioisotope* or, more precisely, *radionuclide*. The choice depends on the needs of the audience.
21. This statement about what we can see requires sensitivity to the fact that some people are sight-impaired and may be more nuanced depending on the audience.
22. Equating nuclear with *unclear* is not to say that the students find distasteful the courses set on nuclear landscapes. On the contrary, over the years these courses have been highly rated and oversubscribed. Rather, the point in describing nuclear as *unclear* is to point out the important role of the instructor in helping to map the potholes in the terrain.
23. Answers: electromagnetic, electromagnetic, nuclear, electromagnetic, and nuclear. Some instructors may not know that the venom of the spider is radioactive (as the story goes). My students taught me this.
24. This passage was written for this course in 2005 by Dr. Jamie Ellis, at the time, a graduate student at the University of Wisconsin-Madison.
25. Tabuchi, H. An Anniversary of 'Heartbreaking Grief' in Japan *New York Times*, March 11, 2012.
26. Not described in this paper are the difficulties that students (actually most people) experience with the units used to measure nuclear phenomena. One set (curie, becquerel) measures the radioactivity of the sample. A second set (rem, sievert, roentgen, rad) measures or estimates the dose received.
27. High School Science, "C&EN examines the impact of dedicated teachers and volunteers, as well as revisions to AP Chemistry. *Chem. Eng. News* **2011**, *89* (37), 54.
28. These are the four modes of literacy. Employing them usually involves the higher level skills of integration, analysis, and synthesis.

Chapter 6

Connecting Head, Hand, and Heart: SENCER and Becoming a Chemist

Matthew A. Fisher*

Department of Chemistry, Saint Vincent College, Latrobe, Pennsylvania 15650
***E-mail: matt.fisher@email.stvincent.edu**

> "Good teachers possess a capacity for connectedness. They are able to weave a complex web of connections among themselves, their subjects, and their students so that students can learn to weave a world for themselves."
>
> \- Parker Palmer

Chemistry as a profession very clearly claims that it has a responsibility to society as a whole and benefits society. The responsibilities of those trained in chemistry are set forth in the American Chemical Society's "Chemical Professional's Code of Conduct." How can we design chemistry courses for majors so that students encounter this statement of professional responsibility in a way that encourages deeper engagement and reflection? The SENCER approach may hold a way that courses can be designed so that students are engaged in understanding both content and context in a way that support the development of their sense of professional identity and responsibility.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

The Broader Responsibilities of Chemistry as a Profession

Professions such as accounting, engineering, and medicine have been broadly described by Shulman and Gardner (*1*) as sharing six characteristics – "a commitment to serve in the interests of clients in particular and the welfare of society in general; a body of theory or special knowledge with its own principles of growth and reorganization; a specialized set of professional skills, practices, and performances unique to the profession; the developed capacity to render judgements with integrity under conditions of both technical and ethical uncertainty; an organized approach to learning from experience both individually and collectively and, thus, of growing new knowledge from the context of practice; and the development of a professional community responsible for the oversight and monitoring of quality in both practice and professional education." While not in Shulman and Gardner's original list, chemistry would certainly qualify as a profession based on their criteria. The specialized set of skills and practices, the body of special knowledge have long been a part of undergraduate chemical education. Some might be tempted to question how central to chemistry is the commitment to serve the welfare of society in general. But the American Chemical Society's (ACS) strategic plan for 2012-2015 (*2*) shows a clear focus - from the vision through the mission and values and ultimately the goals – on how chemistry can benefit society. The Society's vision is "improving people's lives through the transforming power of chemistry" and the mission is described as to "advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people."

There is another way that the ACS points towards the chemist's responsibilities to individuals and society as a whole, "The Chemical Professional's Code of Conduct" (*3*). This statement was approved by the ACS Board in 1994 as a replacement for "The Chemist's Creed" originally approved in 1965. "The Chemical Professional's Code of Conduct" highlights the responsibilities of chemists to the public, science of chemistry, profession, employers, employees, students, associates, clients, and the environment. It makes clear that the profession of chemistry does have a responsibility to society as a whole. The Society's Committee on Professional Training (CPT) guidelines for bachelor's degree programs includes the statement that, as part of developing student skills in ethics, "students should conduct themselves responsibly and be aware of the role of chemistry in contemporary societal and global issues" (*4*). that ACS places great importance on education, as it is the clear focus of one of the four major goals in the strategic plan. At the same time, it is very difficult to find evidence that the "Chemical Professional's Code of Conduct" is something that undergraduate chemistry majors encounter in any systematic way as part of their preparation to join the chemical profession.

How problematic is that absence? William Sullivan has outlined a model for education in any profession (*5*) that he sees as involving three apprenticeships:

- a *cognitive apprenticeship* where the student learns to think like a member of the profession;

- a *skill apprenticeship* where the student practices the skills routinely used by members of the profession;
- an apprenticeship that "teaches the skills and traits, along with the ethical comportment, social roles, and responsibilities, that mark the professional…the novice is introduced to the meaning of an integrated practice of all dimensions of the profession, grounded in the profession's fundamental purpose."

The connection between "The Chemical Professional's Code of Conduct" and Sullivan's third apprenticeship is clear. A quick examination of books such as *The New Chemistry* (*6*) and *Letters to a Young Chemist* (*7*) clearly show many examples of the ethical dimension and social responsibility that is integral to the vision and mission of chemistry put forth by ACS. At the same time, as Peter Mahaffy has so eloquently pointed out (*8*, *9*), the human dimension of chemistry – including any significant engagement of students with "The Chemical Professional's Code of Conduct" and related questions – is noticeably absent from much of undergraduate chemical education for majors. That absence is increasingly problematic in the face of:

- editorials that regularly appear in journals such as *Science* and *Nature* identifying specific challenges and strategies for how science can be used to address important social issues.
- the statement by the World Congress on Science (*10*) that "the practice of scientific research and the use of knowledge from that research should always aim at the welfare of humankind, including the reduction of poverty, be respectful of the dignity and rights of human beings, and of the global environment, and take fully into account our responsibility towards present and future generations."
- Ismail Serageldin's 2002 essay in *Science* (*11*) where he wrote "For science to realize its full promise and become the primary force for change in the world, it requires that scientists work to 1) engage scientific research in the pressing issues of our time; 2) abolish hunger and reduce poverty; 3) promote a scientific outlook and the values of science; 4) build real partnerships with the scientists in the South."

How might we, to use Mahaffy's words, bring the "human element" back into chemistry that would also provide a way to engage students with the various dimensions of "The Chemical Professional's Code of Conduct"? In the guidelines for teaching professional ethics developed by CPT (*12*), the committee identifies three different approaches that departments can use - a guest lecture program, a single course (either new or revised to include a strong ethics component), or integrating ethics into multiple courses throughout the curriculum. CPT's guidelines acknowledge the limitations/challenges of each of these three approaches; they also mention two teaching approaches that are referred to as "the ethics moment" and "the ethics homework problem." But it is not clear from the descriptions to what extent students will see the incorporation of ethics and chemistry's responsibilities to society as a substantive part of their education. Could the SENCER approach offer a more effective approach for chemistry faculty?

SENCER as a Possible Approach

As David Burns wrote in his overview of the SENCER Project (*13*), "the essential maneuver in a SENCER course, or learning community, or curriculum, is a shift in the 'narrative.'" He goes on to write that "context is at least provisionally privileged over content." I have often described the SENCER approach as one that, rather than designing a course around either content or context, designs explicitly around both from the outset. This is consistent with Burns's description of the components of designing an effective SENCER course, where context is the second element he lists followed immediately by the canonical STEM content. The bringing together of context and content in a SENCER course is clearly an example of what Colby and Sullivan (*14*) have described as "deep engagement with the profession's public purposes", which they argue is one of several qualities that will foster life-long engagement and growth in "professional competence and commitment." This deep engagement should provide multiple opportunities to engage students in reflecting on statements such as "The Chemical Professional's Code of Conduct" and through that on the relationship of chemistry to society and the responsibilities our students have as chemists to society both as scientific professionals and citizens. But how well does the SENCER approach work with the content-intensive nature of courses that characterize the undergraduate chemistry curriculum? Examination of the more than 30 model courses developed by faculty involved in the SENCER Project shows that the vast majority are courses for nonscience majors. However, there are a few examples that provide a starting point to answer this question.

The three examples that I want to focus on are a one semester advanced general chemistry course, an instrumental analysis course that overlaps for several weeks with a urban studies class, and a two semester biochemistry sequence for junior and seniors majoring in biochemistry or interested in pursuing graduate or medical studies.

Chemistry 125, the one semester general chemistry course, is a SENCER model course developed by chemistry faculty at Hamilton College (*15*). The course is designed for students coming to Hamilton with a strong background in chemistry. Using the context of environmental exposure to carcinogens and endocrine disruptors , the course engages students in learning a variety of central chemical principles: bonding, polarity, solubility, aqueous chemistry, pH, acid/base chemistry, and analytical methods such as chromatography. Endocrine disruptors are chemicals that may interfere with the endocrine (hormonal) system in living organisms (both human and wildlife) and potentially produce undesirable or dangerous developmental, reproductive, neurological, and immune effects.

The lab course is structured to provide students with a series of more open-ended research-like experiences such as synthesis and recycling of polymers, isolation and characterization of caffeine, determination of iron in supplements, and detection of cocaine on a dollar bill. These experiments share a common thread of the context of health and environmental chemistry. By the end of the lab course, students have been engaged in an analytical assessment of the limits of detecting bisphenol A (BPA) and halogenated flame retardants. Specific projects that students undertook included the effect of ethanol on leaching of BPA, the effect of phosphate, amino acids, and pH on the leaching of BPA, assessing exposure to BPA from polycarbonate cups, and fire retardants in baby products.

Chemistry 362 is, in many ways, a traditional one semester instrumental analysis course taught at Vassar College (*16*). But what makes the student learning experience very different is that the instructors placed a priority in the course design on engaging students as scientists and citizens. As a result, the course interacts for a three week period towards the end of the semester with a sociology course titled "Introduction to Urban Studies". Students from the two courses must work together on the problem of lead exposure in urban environments, an issue of local importance to the town of Poughkeepsie where the College is located. The instructors have named this element of the course design the "Course Intersection method." As the instructors write in the online description of the course in the SENCER digital library (*17*):

> "The Chemistry students, who are mostly science majors, are the scientists on the project. As such they see that the usefulness of their contribution will depend on their knowledge of the problem and their understanding of the civic process that will use their results to shape public policy. In a complementary way, the urban studies students are the policymakers. The urban students are confronted with an urban policy problem: the evaluation of and response to lead (Pb) exposure in an urban environment. Part of the understanding of this problem relies on scientific studies in analytical chemistry, toxicology, and epidemiology in the context of economic and political conditions that set standards and limit the implementation of policy making. Through this joint project the policy makers and scientists must work together to study a real case of lead exposure in their own environment. As a result, students in both classes will see that their chosen field has civic responsibilities as they are exposed to the complexities of putting their knowledge in a wider social context."

For the chemistry majors enrolled in this course, the chemical concepts of spectroscopy, chromatography, and electrochemistry, sampling, calibration, validation, and measurement uncertainty covered earlier in the course now take on a powerful real-world connection. That connection clearly links to various elements of "The Chemical Professional's Code of Conduct." While the course information available online doesn't indicate that either of the chemistry instructors explicitly mention the ACS statement, it seems reasonable to expect that chemistry students who complete this course will have a different understanding of the ethical responsibilities of a chemist than students who take a more traditionally structured instrumental analysis course.

The third example is the two semester biochemistry sequence that I have taught at Saint Vincent since 1995. In the 2005-2006 academic year, I significantly redesigned the two courses so that students engaged with the biochemical content through a variety of public health issues (described in greater detail in references (*18–20*)). Three major elements made up the redesign:

1. Wherever possible, illustrative examples used in class would be drawn from public health topics rather than the examples found in textbooks that had been used for many years.
2. At various points in the course, I would ask students to read and respond to articles that focused on the broader societal context of these public health issues.
3. Students would work in small groups to develop a final "capstone project" on a public health topic of their own choosing.

Public health issues such as Alzheimer's Disease, HIV/AIDS, diabetes, cancer, and neuropsychiatric disorders positioned students to learn underlying biochemical concepts such as protein structure and folding, enzyme function, metabolic pathways, signal transduction, and DNA replication/repair. The inclusion of some reflective writing assignments enabled students to learn about and reflect on what science (particularly biochemistry and molecular biology) can contribute towards solving these problems while also becoming more aware of other factors that affect the impact that science can have. The integrative end of semester "public health project" assignment (described in more detail in reference (*20*)) provided students with an opportunity to bring together their understanding of biochemistry, what they had learned in courses outside the sciences, and values such as care, community, and stewardship that are a central part of Saint Vincent's identity as a Catholic, Benedictine, liberal arts college. Topics chosen by students for the public health projects include alcohol consumption as a cause of thiamin deficiency, dengue fever, gonorrhea, tuberculosis, juvenile diabetes, malaria, shigella, methicillin-resistant *S. aureus*, human papilloma virus, Ebola, and rabies. Several years gathering evidence of student learning have demonstrated that student learning of biochemistry content has not diminished at all. At the same time student engagement is much greater in the courses and students are beginning to connect what they learn in my courses to other general education courses they have taken at Saint Vincent. Those cross-disciplinary connections are similar to the perspectives underlying statements such as "The Chemical Professional's Code of Conduct."

Three Apprenticeships Revisited, Thresholds, and the Next Step

The three courses I have described here, all SENCER model courses, provide clear evidence that courses for chemistry majors can be redesigned so that they align with SENCER principles and still provide students with the necessary chemical knowledge that the undergraduate curriculum requires. Such redesign opens up opportunities to engage students in all three of Sullivan's apprenticeships for professional education, far more than the traditional approach to teaching chemistry that Mahaffy thoroughly critiques (*9*). Sullivan's three apprenticeships bridge both cognitive and affective domains of learning, and an independent evaluation of the SENCER project completed in 2006 showed that students showed gains in both domains. While the vast majority of students whose responses were used in that evaluation were enrolled in courses for nonscience majors, it is reasonable to expect that well designed SENCER courses for chemistry majors could have the same effect. But it is important to acknowledge that none of the three courses I have described in this chapter explicitly looked at possible changes in student understanding of chemistry as a profession and discipline.

My hope that redesigning courses for chemistry majors using the SENCER approach would result in deeper and more mature student understanding of chemistry as a discipline and profession is supported by some recent work done by engineering faculty in Canada (*21*), who focused on social justice as a threshold concept that would challenge student views and understanding of engineering as a profession. Threshold concepts, first described by Meyer and Land (*22*), are concepts that function as a portal that students can pass through to a new understanding of a discipline. Threshold concepts are frequently described as transformative, integrative, and irreversible (*23*). In their work, Kabo and Baillie found that explicit incorporation of the concept of social justice challenges into an engineering course seemed to function well in terms of defining a threshold that changed student understanding of engineering as a discipline and a profession (*21*).

Kabo and Baillie relied extensively on careful analysis of student interviews throughout the course. Unlike pre- and post-tests, the typical way that many chemistry faculty evaluate changes in content knowledge, changes in student views of chemistry as a discipline and a profession will require different approaches. In many ways, the challenge for chemistry educators is what Bass and Eynon have described as the challenge of "making the invisible visible" (*24*). This will require a change in how chemistry faculty designing SENCER courses gather evidence of student learning; more use of qualitative research methods will be needed. These research methods are ones that chemistry faculty are generally not familiar with, but the time required to learn them may be well worth the insight faculty will gain on how students develop their understanding of chemistry as a profession that seeks to "improve people's lives through the transforming power of chemistry" (*2*).

References

1. Shulman, L. S.; Gardiner, H. *Daedalus* **2005**, *134*, 13–18.
2. Strategic Plan for 2012 and Beyond. American Chemical Society. http://strategy.acs.org/ (accessed May 2012).
3. The Chemical Professional's Code of Conduct. American Chemical Society. http://portal.acs.org/portal/PublicWebSite/careers/ethics/CNBP_023290 (accessed May 2012).

4. Undergraduate Professional Education in Chemistry: Guidelines and Evaluation Procedures. American Chemical Society. http://portal.acs.org/portal/PublicWebSite/education/policies/index.htm (accessed May 2012).
5. Sullivan, W. M. *Work and Integrity: The Crisis and Promise of Professionalism in America*, 2nd ed.; Jossey-Bass: San Francisco, CA, 2004.
6. *The New Chemistry*; Hall, N., Ed.; Cambridge University Press: Cambridge, 2000.
7. *Letters to a Young Chemist*; Ghosh, A., Ed.; John Wiley and Sons: Hoboken, NJ, 2011.
8. Mahaffy, P. *J. Chem. Ed.* **2006**, *83*, 49–55.
9. Mahaffy, P. In *The Chemical Element: Chemistry's Contribution to Our Global Future*; Garcia-Martinez, J., Serrano-Torregrosa, E., Eds.; Wiley-VCH Verlag GmbH & Co.: Weinheim, Germany, 2011; pp 131−157.
10. UNESCO. *World Conference on Science: Science for the Twenty-First Century: A New Commitment*; Cetto, A. M., Schneegans, S., Moore, H., Eds.; Banson: London, 2000.
11. Serageldin, I. *Science* **2002**, *296*, 54–58.
12. Guidelines for the Teaching of Professional Ethics. American Chemical Society. http://portal.acs.org/portal/PublicWebSite/about/governance/committees/training/acsapproved/degreeprogram/CTP_005588 (accessed May 2012).
13. Burns, W. D. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 1−23.
14. Colby, A.; Sullivan, W. M. *Univ. St. Thomas Law J.* **2008**, *5,* 404−427. http://ir.stthomas.edu/cgi/viewcontent.cgi?article=1149&context=ustlj (accessed May 2012).
15. Assessing Exposure to Toxic Chemicals: General Chemistry Applied to Human and Environmental Health. http://serc.carleton.edu/sencer/assessing_exposure_toxic/index.html (accessed May 2012).
16. Chemistry and Policy: A Course Intersection. http://serc.carleton.edu/sencer/chemistry_policy/index.html (accessed May 2012).
17. Chemistry and Policy: Linking Science and Social Issues. http://serc.carleton.edu/sencer/chemistry_policy/linking_science_social_issues.html (accessed May 2012).
18. Undergraduate Biochemistry through Public Health Issues. http://serc.carleton.edu/sencer/biochem_public_health/index.html (accessed May 2012).
19. Fisher, M. A. In *Citizenship across the Curriculum*; Smith, M. B., Nowacek, R. S., Bernstein, J. L., Eds.; Indiana University Press: Bloomington, IN, 2010; pp 110−131.
20. Fisher, M. A. In *Sustainability in the Chemistry Curriculum*; Middlecamp, C. H., Jorgensen, A. D., Eds.; ACS Symposium Series 1087; American Chemical Society: Washington, DC, 2011; pp 39−48.
21. Kabo, J.; Baillie, C. In *Threshold Concepts and Transformational Learning*; Meyer, J. H. F., Land, R., Baillie, C., Eds.; Educational Futures: Rethinking

Theory and Practice 42; Sense Publishers: Rotterdam, The Netherlands, 2010, pp 303−316.

22. Meyer, J. H. F.; Land, R. In *Improving Student Learning: Improving Student Learning Theory and Practice – 10 Years On*; Rust, C., Ed.; Oxford Centre for Staff and Learning Development: Oxford, UK, 2003.
23. Land, R., Meyer, J. H. F., Baillie, C., Eds.; *Threshold Concepts and Transformational Learning*; Educational Futures: Rethinking Theory and Practice 42; Sense Publishers: Rotterdam, The Netherlands, 2010, pp xi−xliii.
24. Bass, R.; Eynon, B. Academic Commons, 2009. http://academiccommons.org/commons/essay/capturing-visible-evidence-invisible-learning (accessed May 2012).

Chapter 7

Bringing SENCER's Civic Engagement Strengths to Large Research Universities: A "Trojan Horse" Hybrid Model To Initiate Incremental Course Reform

Garon C. Smith*

Department of Chemistry and Biochemistry, The University of Montana, Missoula, Montana 59812
***E-mail: garon.smith@umontana.edu**

A variation in the pedagogical model for SENCERizing a STEM course is proposed that can be easily applied to any large, introductory, undergraduate courses. Called the "Trojan Horse" Hybrid Model, it weaves a family of complex social issues into the curriculum yet allows retention of a traditional text. Each of the complex issues is systematically and repeatedly visited as underlying concepts that help "uncover" them are encountered. An out-of-class scheme is also described to encourage students to actually participate in civic engagement activities in their community. An embedded "honors" section can be implemented as a more purely SENCER experience for a selected smaller group of students.

The SENCER project is a highly effective pedagogic approach for the undergraduate STEM disciplines that has made significant inroads in higher education for more than a decade. At its core is helping students harness the power of science and technology to advance civic engagement and social responsibilities. A SENCER course challenges students to resolve complex, capacious, contentious, current problems. It teaches *through* real-world issues that affect a community *to* the underlying scientific concepts. As students work towards finding answers, the core technical content of the course is uncovered - the biology, the chemistry, the geology, the mathematics, the engineering. By

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

making the content immediately relevant to the problem at hand, a powerful motivation for learning is created. While this seems a laudable goal for all STEM education, the majority of STEM courses in our institutions of higher education are not organized in this manner, especially the large-format introductory courses at major research universities. This chapter describes an alternative that may be able to bring the benefits of SENCER into these vast, untapped student audiences.

The majority of SENCER courses to date have been developed and established at smaller, predominantly undergraduate institutions (PUIs), often in non-majors courses. Why is this? First, SENCER courses by nature are student-centered learning. Organizing and running a student-centered curriculum runs into huge logistical problems with large introductory courses. Without major infrastructure changes, there are simply insufficient personnel to cover the small-group interactions that must occur. Second, many large introductory courses have "sacred cow" content that forms the gateway to the balance of coursework in a disciplinary program, course content that is often specified and "required" for degree certification by professional societies. Major texts are written and marketed with this mandated content in mind. Third, teaching large introductory classes severely hampers a faculty member's ability to pursue funded research. These gargantuan courses consume so much of the instructor's effort that there is little time left to generate proposals and write peer-reviewed publications. Thus, large introductory courses are usually shunned by faculty who seek promotion and tenure along a more secure path. Not infrequently, large introductory courses are taught by lecturers as opposed to tenure-line faculty.

Does SENCERizing large introductory courses at major research universities have three strikes against it? No. Should we bypass the opportunity to civically engage the huge number of students enrolled in these courses? No. Every student in every STEM course should be connecting its content to significant issues. It is time to bring as many large research universities and their majors' courses as possible into the SENCER fold. It is time to forge synergistic goals by partnering the SENCER community with the various professional societies – the American Chemical Society (ACS), the American Institute of Biological Sciences (AIBS), the Geological Society of America (GSA), the Ecological Society of America (ESA), the American Physical Society (APS), the Mathematical Association of America (MAA), etc. But it may take a bit of rethinking and a different game plan to sell it. Since the symposium that spawned this book was organized under the auspices of the ACS, this particular chapter is aimed toward the large introductory chemistry courses. But there is no fundamental reason why the same approach should not work just as well for other disciplines. Which, among any of the professional STEM societies, would argue against one of their important goals being "to prepare college graduates who will be active, engaged citizens upon degree completion"?

While examining the "sacred cow" contents of our large introductory classes, as scientists we should also admit to a bit of disciplinary delusion. It is this: The vast majority of students in our large introductory classes are not going to major in the discipline of the course itself. Nowhere is this more true than in chemistry. At my home institution, The University of Montana, we annually enroll about 1,500 students in our introductory courses, yet the largest graduating class of chemistry majors we have ever produced is 23. We seem to forget that everyone in the lecture hall is not poised for a major in chemistry, so we cram content into the introductory courses as if it were an imperative for all future coursework. Would we not better serve our student audience by replacing at least part of the content with practice in using science and technology to solve some of our most pressing problems – developing sustainable clean energy, curbing global climate change, reducing emissions of toxic substances into the air and water?

This chapter advocates a hybrid course model, one that preserves the content appearance of the traditional course, yet embraces the SENCER approach of teaching *through* complex issues *to* underlying scientific concepts. This hybrid model is a "Trojan horse" of sorts because it allows dramatic reforms to be made toward SENCER goals without any noticeable outward signs. It retains the core of scientific concepts as they are typically developed in a traditional course. But at every opportunity, with almost every sample calculation, the material is immediately applied to a family of complex issues around which the semester's work is focused. Issues are introduced in a staggered fashion early in the term, but are revisited repeatedly as new concepts are uncovered with each chapter. By the semester's end, students have integrated the issues with the technical concepts every bit as much as in a pure SENCER-style course. It is just the route that has been varied a bit.

This chapter provides details on how the civic engagement approach of SENCER is integrated into The University of Montana's large CHMY 121 Introductory to General Chemistry class. To all external appearances, this course is entirely traditional. Its content is a sensitive issue in that CHMY 121 comprises the first half of a one-year survey course for applied science majors. The faculty member who teaches the second semester sequel depends on specific concepts and skills being in place. My more pedagogically conservative colleagues are still unaware, despite ten years of offerings, that its content has been rather dramatically manipulated. There was no new course that had to be approved, no shift in departmental teaching loads that was required, and no change in the textbook whose second half is used by a non-SENCER teaching partner.

Assimilating SENCER Ideals into a Traditional, Content-Driven Lecture Course

SENCERizing a course can be done to differing degrees. For the most purely SENCERized course, one needs to throw away the chapter sequence of a traditional text and restructure the course materials around the course's unifying theme. One starts with an issue and then masters whatever concepts and content are needed in working toward understanding and making recommendations for its resolution. This pure-SENCER framing is illustrated in Figure 1. SENCER course themes are by nature interdisciplinary, so a single text that meets the breadth of the problem is not likely to be found. Instead, a broad collection of source materials will be needed. Existing models of this type (available at http://www.sencer.net/Resources/models.cfm) include: Chemistry and the Environment (Amy Shachter, Santa Clara University); Chemistry and Ethnicity:

Uranium and American Indians (Cathy Middlecamp and Omie Baldwin, University of Wisconsin-Madison); and Chemistry of Daily Life: Malnutrition and Diabetes (Matthew Fisher, St. Vincent College).

The approach suggested in this chapter is a hybrid model between a purely SENCERized course and the traditional STEM course. To put it into practice, one simply chooses a set of issues to explore over the course of the semester. Then, at every feasible opportunity as one works through a standard course treatment, one connects each concept with one or more of the issues. Figure 2 attempts to depict this strategy with "flower petals" signifying a multiplicity of links from various concepts to each of the complex issues. Since it employs the traditional sequence of topics, it allows one to use a standard text and produce a syllabus that will not arouse undue suspicion or criticism from non-SENCER colleagues and administrators. And by semester's end, hasn't the same journey been accomplished? The destinations seem the same; it is just the itineraries that are a bit different.

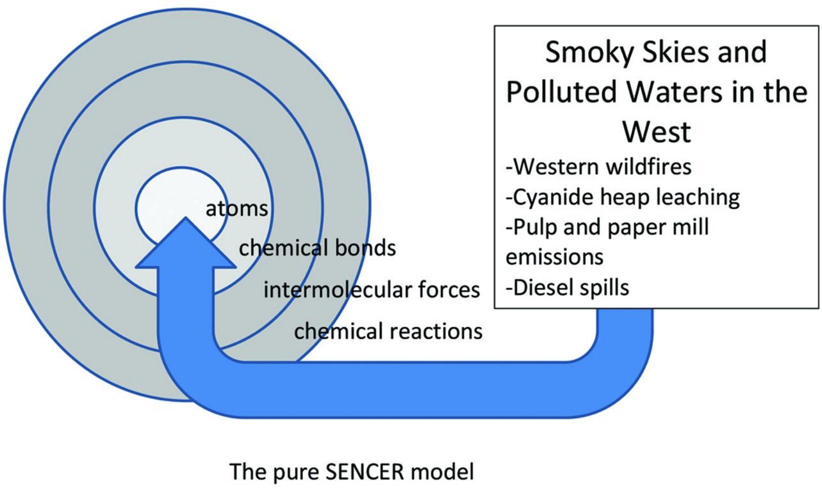


Figure 1. Teaching through an issue to the underlying scientific concepts. An example of how Chemistry 121 course might look if retooled as a pure SENCER course.

The hybrid course easily hides within the rest of an established curriculum with no administrative buy-in needed or "return-to-normal" transition at the end of the course. It also allows an instructor to try a low risk experiment in this pedagogical approach by inserting one or two SENCER modules into his/her existing course on a trial basis. The ultimate aim in pursuing this approach is to experience so much positive feedback and results regarding the SENCER modules that one will want to expand upon them. Even better, if one's modifications yield a good student response, others on your campus might feel compelled to

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

follow one's lead. With careful coaching, they can be drawn into the SENCER fold without ever fully realizing that they are being transformed. Once hooked, making a deeper commitment toward SENCERization becomes less contentious and easier to promote across a campus.

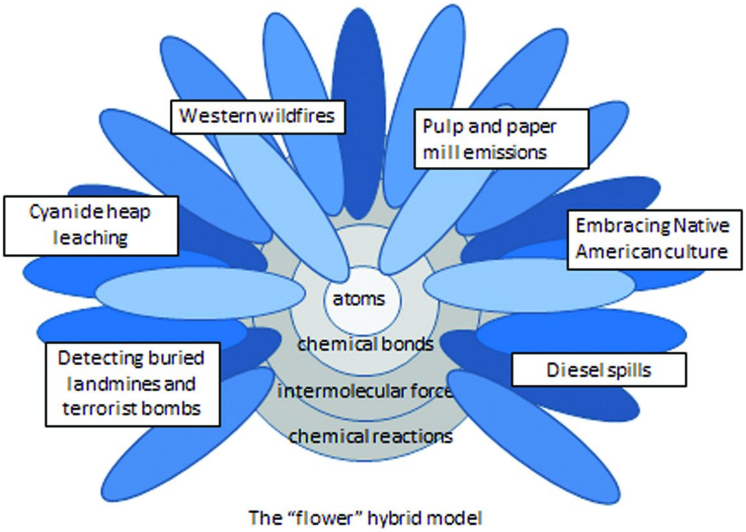


Figure 2. The "flower" hybrid model. Frequent SENCER pedal connections are made between core concepts and a family of complex issues featured over the course of the semester.

There are two parts to implementing a hybrid SENCER course. First, the contents of the course must be linked to one or more SENCER-style themes. Second, students must be mobilized into taking action with their new-found knowledge.

Step 1. Choosing Course Themes and Tying Them to Content

In a hybrid SENCER course one simply expands on and formalizes what is normally found in a good textbook anyway – marginalia and special topic boxes. Textbook authors frequently help students connect a concept to real-world applications through photographs, schematic diagrams, margin notes and strategically placed short applications articles (the special topic boxes). For a hybrid SENCER course, rather than let the authors dictate the course connections, the instructor chooses in advance one or more meaningful complex, capacious, contentious, current problems on which to focus over the duration of the course. The selections are introduced to the students at the front end of the course.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Students are told that the course contents will arm them with specific knowledge needed to understand the scientific aspects of the problems, will help them formulate meaningful opinions regarding possible actions, and ask them to engage in community conversations or debates concerning the issues. At its best, the themes selected also relate to the students who populate the course. When done correctly, the students have no problem in accepting why the course is required for their majors. It is not unusual, after a few weeks into the course, to have the non-chemistry majors ask, “Are you sure this is a chemistry course?!”

The themes in The University of Montana CHMY 121 Introduction to General Chemistry course, which has been run as a hybrid SENCER course for more than a decade, are primarily based on my own research and personal roles in formulating science/environmental/health policy at the local and state levels. My work includes tracking air and water pollution in western mountain valleys (including wildfire smoke), toxic emission reductions from kraft paper mills, training honeybees to find hidden/buried explosives via olfaction, understanding the growth and structure of snowflakes, and nurturing ethnic diversity by revealing the scientific basis behind cultural practices of Native American peoples. From my position on environmental boards, I add cyanide heap leaching of gold ore, spills of railroad diesel into groundwater, and use of pentachlorophenol (pcp or penta) as a wood preservative. As each chapter unfolds, I constantly reflect on just how many places I can tie the course content to these themes. I view every illustrative example and every sample calculation as another opportunity to strengthen the connection. Here, by example, are a few of the connections used each semester:

Tracking Air and Water Pollution

Nitrogen dioxide (NO_2) and nitric oxide (NO) are EPA criteria air pollutants. They are health hazards because they are highly reactive radical species with unpaired electrons that can easily interact with mucous membranes and lung tissues.

Course tie ins: **Chapter 3 – Chemical Bonds.** Students construct Lewis structures for these two species. It is quickly apparent that, with an odd number of valence electrons to use in completing the structures, not all electrons can be paired. NO_2 has 5 e^- + (2 x 6 e^-) = 17 e^- while NO has 5 e^- + 6 e^- = 11 e^- to use.

Chapter 7 – Reaction Rates and Chemical Equilbrium. A simulation of the production of photochemical smog via a 17-reaction mechanism shows NO being converted to NO_2 and then NO_2 subsequently reacting with alkenes to generate aldehydes, ozone and peroxyacetyl nitrates (PANs). Catalytic converters are installed to reduced the alkene reactants that generate photochemical smog

The chemical equation for the formation of NO from N_2 and O_2 is used to illustrate how the magnitude of an equilibrium constant can be interpreted to reveal the spontaneous direction of a reaction. Its value is 4.7×10^{-31} at room temperature, ridiculously small, so the atmosphere is in no danger of suddenly having its major constituents turn into NO if someone lights a match.

Carbon monoxide is another EPA criteria pollutant for which Missoula was designated a Clean Air Act “nonattainment area” in the past.

Course tie-ins: **Chapter 3 – Chemical Bonds.** The toxic nature of carbon monoxide is revealed by constructing its Lewis structure. Students can see that the carbon cannot form four bonds as it usually does. This leads it to bind strongly to the iron atom in hemoglobin to form carboxyhemoglobin which is ineffective in delivering of oxygen to cells.

Chapter 6 – Solutions and Colloids. Carbon monoxide levels in Missoula illustrate the use of parts per million as a concentration unit. EPA through the Clean Air Act requires the 8-hour time-weighted average for carbon monoxide to be lower than 9 ppm. Missoula last exceeded this limit in February 1991 and was designated a “maintenance area” in 2006, a twenty-year probationary period. A map of measured CO values for various intersections around the city (Figure 3) shows students that the city has made great strides with respect to this pollutant.

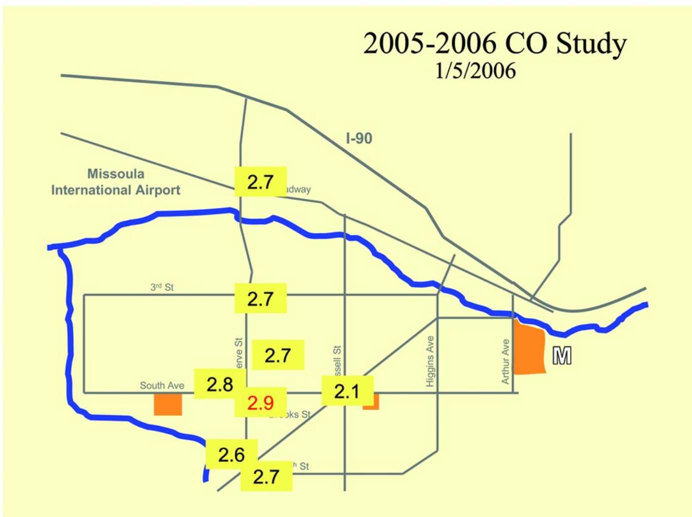


Figure 3. CO values in ppm on January 5, 2006 for various sample locations in Missoula. A violation occurs at 9.0 ppm.

Toxic Emission Reductions from a Kraft Pulp Mill

The kraft pulp process utilizes a pair of interlocking recycle loops that regenerate the pulping chemicals. Missoula had a very prominent mill to the west of the city until 2011. Many residents and students worried about the toxic emissions it released. Almost an entire period is invested in illustrating how ideal an industrial scheme the kraft pulping process is by describing the chemical recovery steps (Figure 4).

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

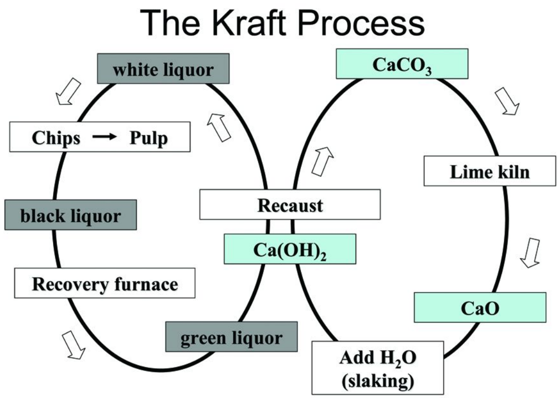


Figure 4. The two interlocking recycle loops that comprise the kraft pulping process. Wood chips are converted to pulp by white liquor ($NaOH + Na_2S$). Black liquor is $Na_2CO_3 + Na_2SO_4$ + lignin. Green liquor is $Na_2CO_3 + Na_2S$.

Course tie-in: **Chaper 4 – Chemical Reactions.** The lime kiln reaction becomes the first stoichiometry problem

$$\underset{\text{lime mud}}{CaCO_3(s)} \overset{\text{heat}}{\Rightarrow} \underset{\text{quicklime}}{CaO(s)} + CO_2(g)$$

The CO_2 released as a by-product from the kiln is from biomass and is more greenhouse neutral than fossil fuel based CO_2 emissions. As a follow-up assignment, students compute how much fossil fuel CO_2 is released each day by Missoula's motorists (Figure 5). The answer is 5.89×10^8 g/day.

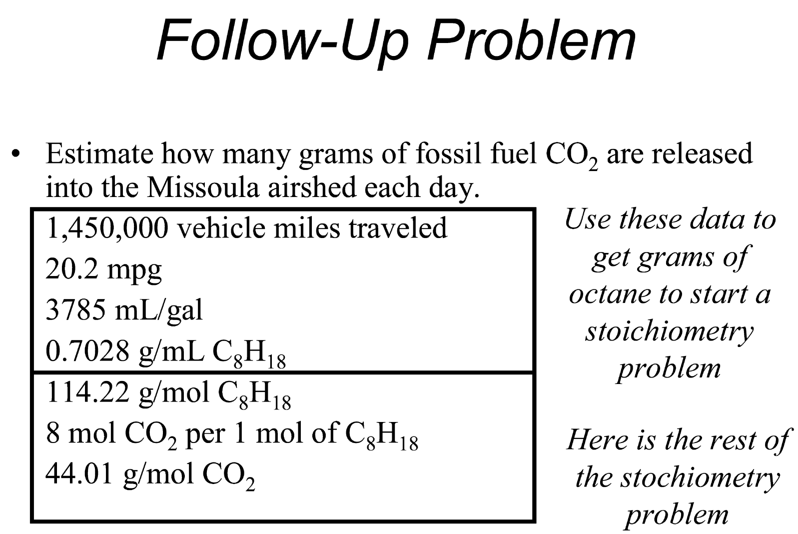


Figure 5. Set-up for stoichiometric follow-up problem.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Chapter 5 – Gases, Liquids and Solids. The formation of a sheet of kraft paper involves essentially a hydrogen bond zipper. This is a perfect application of intermolecular forces that are discussed in this chapter. Cellulose fibers have an abundance of hydroxyl groups with H-bonding possibilities. Without going into more detail about the cellulose structure, I show the students two simplified fibers interlocking (Figure 6).

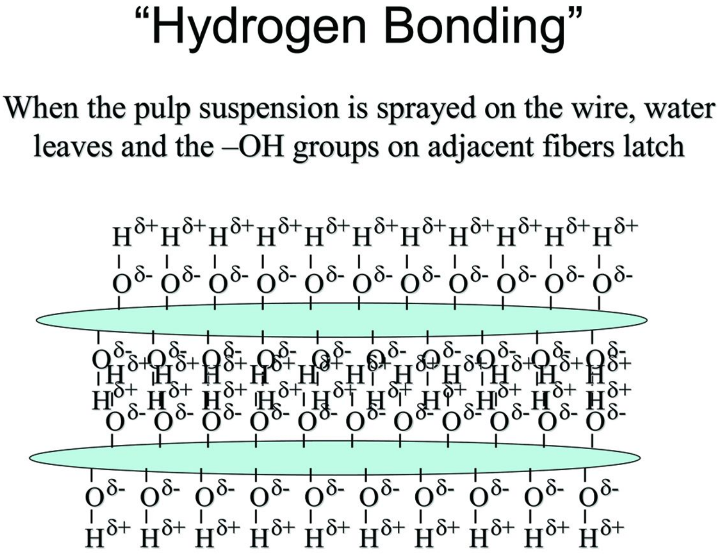


Figure 6. A simplified diagram of two cellulose fibers interlocking via hydrogen bonds to form a sheet of paper.

Native American Cultural Practices

Making Indian "ice cream" from buffaloberries. Photos of the plant and berries are shown, followed by the structure of the saponins found in the berries (Figure 7).

Course tie-ins: **Chapter 6 – Solutions and Colloids.** Solubility concepts can be addressed in pointing out the polar end of the molecule with many oxygen atoms *versus* the nonpolar end that is pure hydrocarbon in nature. Because"like dissolves like", it is easy to understand how the saponins act as a surfactant that stabilizes the colloidal foam of the Indian ice cream.

Baking camas bulbs in early summer. Photos of the plants are shown plus pictures illustrating the various stages of preparing and baking them. Camas supplied an important source of dietary carbohydrates for Native Americans before the advent of westward expansion. But the carbohydrates are principally inulin, a chain of fructose sugars for which humans have no digestive enzymes. The bulbs must be baked four days to hydrolyze the inulins to fructose. The resulting baked form is both sweet and digestible.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

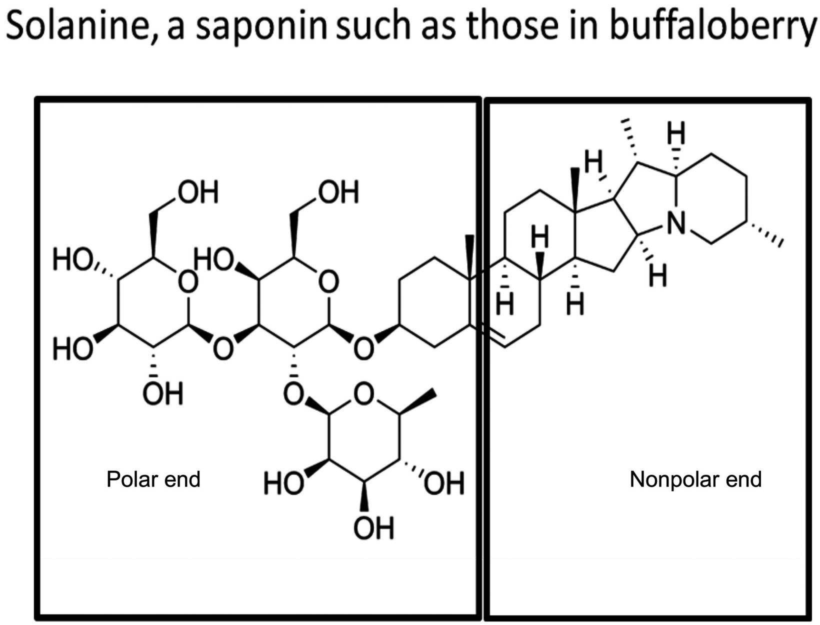


Figure 7. The polarity character of the opposite ends of the saponins found in buffaloberry.

Course tie-ins: **Chapter 7 – Reaction Rates and Chemical Equilibrium.** Digestion of starch at body temperature is an example of enzymes as catalysts. Without enzymes, starch would be inedible. This serves as an anticipatory introduction the topics of carbohydrates (Chapter 20) and enzymes (Chapter 23) that will arise in the sequel course CHMY 123 Introduction to Organic and Biochemistry.

The examples cited above are representative of how the CHMY 121 course is filled with rich but real examples. As each new chemistry concept is introduced, it is immediately related to one or more relevant issues that need our societal attention. If there are no applications from my own work, a quick jump to issues of a regional, national or international scale is made. As might be expected, global climate change comes up with frequent regularity. The text provides the logic around which to organize the sequence of topics – atoms, bonds, reactions- but the SENCER aspects make any new concept relevant by immediately going to an issue that could benefit from its application.

Step 2. Cajoling the Students into Civic Engagement

Once the SENCER approach has been used to infuse course content with relevance, the next dimension of the SENCER process is to prompt students into civic action. There may or may not be a direct link between the SENCER issues and what the students actually do. While small classes can be tasked with a very specific project on which to work, this is not easily accomplished with a large lecture class of 700 students. It is sufficient to get the students to participate in anything that gets them outside of taking care of their own creature comforts, somehow contributing time and effort in helping someone else. An important facet of a civic act in CHMY 121 is that it must take place outside of class time. This approach means that a content-driven curriculum suffers only a small amount of "time-stealing" in order to add this to a course. The only stolen time is that required to describe potential activities in which to participate.

The best activities are those that transfer and apply course content. Second in preference are activities that will be good resume builders within an individual student's chosen field. Ultimately, however, any kind of community service efforts in which the students participate can be accepted. It is important to be expansive in accepting what constitutes civic engagement. As many students as possible should experience the joy and satisfaction that comes from giving of oneself and one's time.

The hook that usually gets student buy-in on civic engagement is extra credit. It is one of the most attention grabbing phrases in large, required courses. The current rate of pay in CHMY 121, which has evolved to more strict upper limits, is as follows:

- 3 points per hour for the first 8 hours of activities
- 2 points per hour for the next 12 hours of activities
- 1 point per hour for the next 24 hours of activities
- Total possible points: 72 (out of a course total of 750 points)

Thus, a determined student can bring his/her overall course average up nearly one whole grade level with a volunteer effort of 44 hours. A few students each semester accomplish this.

Civic engagement activities can be made mandatory, but it is preferable to have the contributions come from a sense of altruism rather than obligation. Too little effort is spent in our education system to nurture such attitudes. Strong communities and strong national identity stem from everyone contributing through volunteerism, to the "good of the whole". The extra credit tallies are prominently displayed each week on the grade spreadsheets, so everyone in class can see what others are doing. In a sense, peer-pressure drives participation as opposed to a grading-scheme requirement. More than 92% of the students do at least one out-of-class activity for extra credit, so the system seems to be working as intended.

The campus and the Missoula community as a whole are well aware of the sizeable body of potential volunteers that CHMY 121 can supply. Some of them start (and finish) their annual recruitment by coming to the class. Almost daily there is a selection of suggested extra credit activities. Some of the annual offerings include:

Missoula Flagship – a program to keep at-risk kids engaged in healthy, after-school activities. This operates at three Missoula elementary schools, three middle schools and four high schools. Students are assigned an activity with which to assist – homework zone, robotics, rocketry, foreign pen pals, staying fit, etc. They

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

are screened, attend a training session and then work with their kids two hours per week, usually under the supervision of a more senior leader. During the Fall 2011 semester, 65 students contributed more than 1300 hours of mentoring for young students who think college kids are much "cooler than to hang with" than grown-ups!

Missoula City-County Household Hazardous Waste Days – an annual drive to properly dispose of toxic chemicals (pesticides, used oil, antifreeze, paints, pharmaceuticals). Students attend a training session, are provided with protective clothing and then help interview drivers and sort containers that are brought in for the event. Students sign up for 2-3 hour shifts. Each fall about 20 students get firsthand experience with the responsible disposal procedures for toxic substances.

Montana State Science Fair – an annual spring event hosted by The University of Montana. Students provide most of the judges for the middle school division. They attend a training session (with lunch) and then participate in one to three 2-hour rounds of judging. About 35 students were judges this year.

University of Montana Conference on Undergraduate Research and Creative Activity – an annual celebration of undergraduate projects in all disciplines. My students, about 75 in number, help with conference set-up, staff the registration table, assist with poster sessions, moderate the oral sessions, and help take down the conference equipment. Many of my participating students are inspired to engage in undergraduate research after helping with this conference.

Students are invited to come up with their own activities for volunteer service. Activities that will bolster their resumes are encouraged. The extra credit volunteer projects make great material to include in letters of recommendation. Many students excel in the course and ask for letters documenting their contributions. There are some predictable activities that attract their interest every year:

For Wildlife Biology and Forestry Majors

Montana Department of Fish and Wildlife – assist at hunting season check stations

Wind River Bear Dog Ranch – care and training of Karelian dogs used to save black and grizzly bears

Wolfkeep – care and feeding of a rescued artic wolf pack and a declawed lynx

Tangle Free Montana – removal of abandoned barb wire fencing that endangers wildlife

Watershed Education Network – serve as classroom contact for an elementary or middle school class that is monitoring a local reach of a river for nutrient load, pH, temperature and biodiversity

For Allied Health Care/Nursing Majors

Ronald McDonald House – staff the reception desk and assist families with infants in Community Medical Center's Newborn Intensive Care Unit

St. Patrick Hospital and **Community Medical Center** – various volunteer positions

Relay for Life – annual fund-raiser for the local chapter of the American Cancer Society

For Health and Human Performance Majors

YMCA Active 6 program – exercise program for elementary students

YMCA Soccer – coaching of soccer teams K-8

Montana Special Olympics – assist with annual sports event for handicapped competitors

There are always special opportunities that arise for students to become engaged in unique service roles. Some from recent years include:

USDA Forest Service Intermountain Fire Sciences Laboratory 50th Anniversary – staff sign-in desk, answer questions and run specific hands-on learning activities for visitors and their children

The 2010 National Conference on Undergraduate Research (NCUR) – The University of Montana hosted over 4000 students, faculty and administrators for this 3-day celebration of undergraduate scholarship. Students were campus guides, session moderator assistants, media trouble shooters and registration center workers.

Election years – Students are prompted to become involved in campaign appearances of candidates for upcoming elected positions. Questions are suggested that they might like to hear candidates address.

An essential and time intensive aspect of having students participate in civic engagement activities is confirming and tracking all the points that students earn. Many of the organizations who use students as volunteers track their names and hours. For other types of activities, students bring in a memo from one of the people supervising the activity, preferably on the organization's letterhead. In the grade spreadsheet, a column is dedicated for each event that is formally announced to the class as a possible extra credit activity. There is also a catch-all column for those projects that the students dream up on their own with a companion column to hold a descriptor of the activity. In this way, every single point a student has earned can be confirmed. All extra credit points are summed into a master column that appears each week on the posted spreadsheets which also contain quiz results, exam scores and the current overall average. Students carefully track extra credit; one can hear remarks about needing to catch up with others in the class who are gaining a nice advantage with their extra points.

So, given this extra credit system, who uses it and to what extent? The answer is: almost every level of student plays the extra credit game (Figure 8). The good students are almost as likely to pursue extra credit as poor students. High-end students like to build up a cushion for a bad day in the future or so that they can ease off in the face of a time crunch occasioned by another course. Students with lower averages, of course, hope to bring them up somewhat.

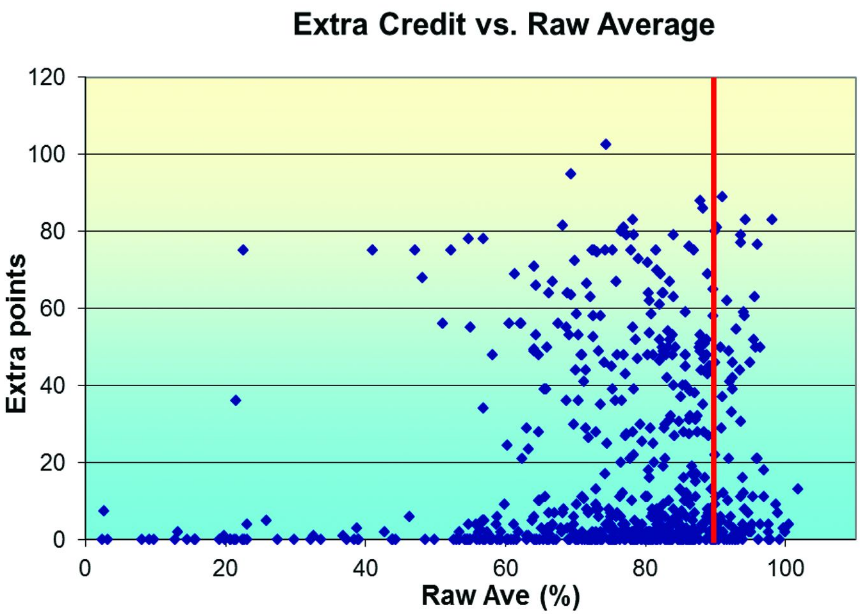


Figure 8. Distribution of extra credit totals versus raw quiz/exam average. The vertical line is at 90%, a guaranteed A in the course.

What's the overall impact of the extra credit? The majority of the students take part in the program. During the Fall 2011 semester, for example, 92% partook of the extra points (Table 1). In accumulating 14,182 points, the students provided the community with 6,474 hours of service. How much did the extra points contribute to grade inflation? For the class as a whole, the average of 21.8 points/student equates to a 3.6% inflation rate. In exchange for nurturing a spirit of volunteerism.in my student body, 3.6% inflation seems acceptable.

Table 1

Fall 2011	
Total enrollment completing the course:	641
Number of students with some extra credit:	588 (92%)
Total points awarded:	14,182 points
Average points/student:	21.8 points
Total civic engagement time:	6,474 hours

Cumulating the impact over the 10-year duration of the CHMY 121 hybrid SENCER course, a total of 7,369 students have chosen to become civically engaged in local and global issues (Table 2). The 142,630 extra credit points they earned while providing 67,919 service hours to their communities were all prompted by an introductory chemistry course. It is numbers such as these that underline why it is so important to get as many our larger universities as possible pursuing this sort of course design and civic engagement.

Table 2

Total Impact Fall 2002 – Spring 2012	
Total enrollment:	7,369 students
Total extra credit points awarded:	142,630 points
Total engagement time:	67,919 hours

Building Civic Leadership—An Embedded SENCVER Honors Section

Embedded within the large lecture class is an honors section with an enrollment of twenty. This is a select group of highly-motivated, highly talented students in whom leadership skills are developed in a more purely organized SENCER fashion. Enrollment is offered preferentially to students who are members of The University of Montana Davidson Honors College, but is open to others on a space available basis. It meets an extra hour each week for an additional credit as HC 195 – Environmental Policy Practicum. During the first third of the semester, the class and I take turns bringing up issues that need attention – local, regional and international – and what action might be possible. As chair of the local health, air and water quality boards, I let the students know the specific issues that are up for public debate during the semester.

The course endeavors to emulate the maxim to “think globally, act locally”. The class selects a local issue in which they want to engage as well as a regional, national or international issue on which they would like to work. They devise a

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

plan through which they can become active locally. They are coached that the most rapid way to make progress is to partner with any entity they are hoping to change. Things done in the spirit of cooperation are orders of magnitude faster than seeking change through a regulatory hammer. Trying to push reform through regulations and enforcement will consume years of effort. Partnerships, on the other hand, can be started and yield results within a matter of weeks. They are counseled to find out who makes the decisions and attack the power structure as directly as possible. If an issue involves something that will be heard by one of my boards, I brief them on who the players are, what their positions will probably be, and what tack the players will take in trying to influence the outcome. I often tell the class how I would like the issue resolved (with evidence to support my position) and reveal the sound bytes/strategies that I intend to employ. They attend the hearing to see how the debate plays out. They are encouraged to speak up and provide testimony if they are willing. Afterwards, a post-hearing critique is conducted to see how well I did. I feel smug when one of my pre-announced sound bytes appears in the news coverage.

While the entire class is encouraged to attend student government senate meetings (ASUM), the honors section students are prompted to consider running for a senate seat. Many of the students have been quite successful in this. Usually about a third of the student senators are former members from this honors section including two student body presidents and three vice-presidents in the past five years. One student went beyond student government aspirations; he ran for and was elected to a seat in the Montana House of Representatives. This year, last year's ASUM president is running for a Montana House seat in the November 2012 elections. She has already won her primary race.

Civic engagement on bigger issues is addressed by designing a fundraiser so that the class can send a financial donation to the organizations they deem most worthy. They spend several weeks discussing how to get the most mileage out of the funds that they generate. This is usually a novel experience for the students. They consult evaluatory websites such as http://www.charitynavigator.com to help them assess the extent that administrative costs and marketing divert dollars away from doing the actual work. It is interesting how incensed they are when they find an organization that siphons off huge sums for an outlandish CEO salary. They usually opt for a local group that spends little on hype and visibility. Often, after an organization is selected, arrangements are made for the students to meet with or talk to (via speaker phone) one of the organization's staff members. Many have actually visited the class – one from an orphanage in Nepal who just happened to be in the area for another function. This is unique in the students' experience.

When the students are ready to select the organizations they wish to support, I make sure that I do not unfairly bias their selections towards my inclinations. To give them complete ownership in their exercise, I leave to buy treats while the class decides who they will support and how the proceeds will be apportioned. They can pick as few or as many as they wish. Incidentally, from the class decisions it is possible to assess which class members have the most effective leadership skills in promoting their personal interests. Over the ten years this project has been in operation, a wide variety of groups have been aided by my honors section. Here are a few year's examples:

2004

- Strong Like a Willow: A Belarus Relief Project
  - Safe school food for schools downwind from Chernobyl
- Adopt a Panda: The Nature Consevancy
  - Critical panda habitat in China
- The Global Reef Alliance
  - Preservation and restoration of coral reefs

2007

- Central Asia Institute
  - Schools for Muslim girls in Pakistan
- Save the AIDS Orphans – Uganda
  - AIDS education and prevention in Africa
- African Medical Research and Education Fund
  - Safe, potable water for African villages
- Heifer International
  - Sustainable protein (2 rabbit trios, geese pair, duck pair, chicken flock) for Third World villages

2011

- The Povarello Center
  - Food and shelter for Missoula'shomeless and transient population
- KIVA*
  - Low interest loans for developing country entrepreneurs

* The 2011 class was particularly pleased to start an honors section KIVA account. This is a revolving loan fund that is paid back by the small entrepreneurs in whom the class invested in December 2011. Each class member got to select a project to sponsor. There were 16 class members plus myself. The small $25 loans went to 17 different Developing Countries. As it is rapaid, it becomes available for each successive year's class to reinvest. Future classes may choose to increase the loan principal with new fund raising profits.

The actual fundraising drive is carried out over three days toward the end of the semester. Tables are set up near the central dining hall and in the atrium of the University Center. The honors section students staff the tables in pairs from 8 am to 5 pm, make promotional posters to catch peoples' attention, and make in-class presentations to their 680 classmates about the organizations they have selected and why they were chosen. The suggested donation is a dime. Few people will refuse to give ten cents. Sufficient numbers of small donations can add up to a substantial amount. Of course, many donors offer more. The class typically collects $600 - $950. The goal is not to necessarily run a huge capital campaign, but to show them how to organize and conduct such an event as well as demonstrate that they can have an effect on an issue half-way around the world. The honors students get so motivated once they start that several times pairs of them have canvassed the dorms for donations and another pair got permission from a local grocery store to solicit donations at the store exit. The Honors Dean frequently cites the honors section as an example of how honors courses differ from regular ones. He remarks that, in honors courses, the students go beyond the classroom boundaries, out into the world as a whole.

The "final exam" for the course consists of counting up the money and composing the donation letter. Every student gets to sign the donation letter that accompanies the check. The students are aglow with an altruistic flush. They remark, "We not only talked about the problems, we actually did something about them!" Responses that come from recipients of the donations are posted in the Honors College foyer for everyone to enjoy.

"It was a special and unexpected delight to learn of the support of the Honors Chemistry Course at the University of Montana and receive the kind donation to the Global Coral Reef Alliance they raised from the students at the University. We were delighted that people living so far from the ocean, and even further from coral reefs, care so much about these issues to help our efforts to restore ecosystems a world away… These days, so many students only want to know what is on the exam. So it is truly encouraging to see that you and your students have used funding from NSF SENCER to actively research local and global applications of chemistry for social and environmental betterment and choose those they wish to support. We are very grateful that your students found out about our work on their own and arranged a fund raising and consciousness-raising drive among their fellow students."

Over the ten-year period of the project, they have generated more than $8000 in funds to assist with world health issues, the education of girls in Third World countries, wildlife habitat, local foodsheds, and environmental policy -- another significant civic accomplishment from an introductory chemistry course. Again, the scale of the impact and the numbers of students involved argue for the need to pursue SENCER activities at large universities.

What Are We Waiting For?

Every semester that passes represents another opportunity lost to help students connect their STEM course content to problems on which we need to be actively working. Given that the SENCER "flower pedal" model can be implemented at minimal risk, at minimal cost and in small increments, the SENCER community should be more aggressively spreading the idea. Because the "Trojan Horse Hybrid Model" approach can be accomplished through a series of stand-alone modules, as a pedagogic team we could work toward creating a collection of modules for sharing with others. There are bound to be common regional themes or timely issues that will appeal to faculty at a number of institutions.

My experience with the "Trojan Horse" hybrid SENCER course has been overwhelmingly positive. Students seem to enjoy their SENCERized semester because enrollments have been rising since (Figure 9). Most recently, the 2011 fall term saw 696 enroll while 288 more signed-up for the trailer section in the 2012 spring term. Who is my student audience? About 40% of the students are majoring in programs within our College of Forestry and Conservation – forestry; resource conservation; wildland restoration; wildlife biology; and parks, tourism and recreation management. Around a third of the class is from allied health care fields, predominantly nursing and physical therapy. The remaining students seek degrees in exercise science, athletic training, environmental studies, journalism, education and forensic anthropology.

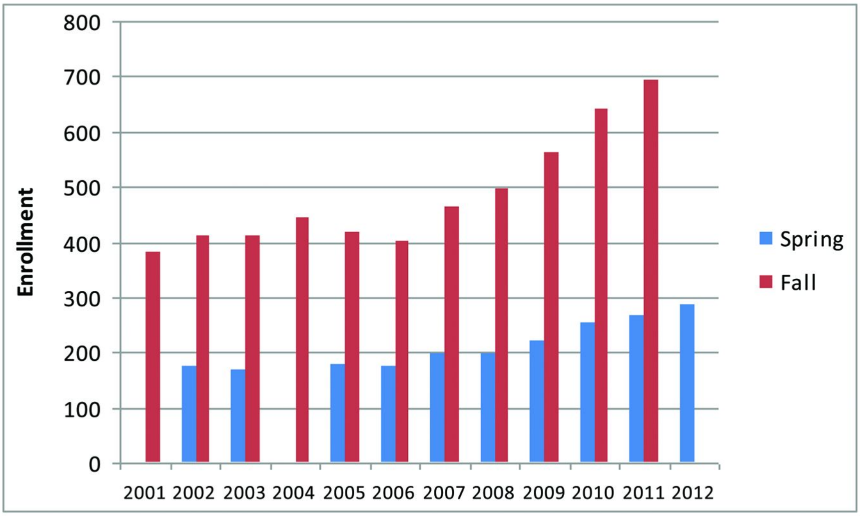


Figure 9. CHMY 121 enrollment by term. (Note: Spring 2004 sabbatical leave at the SENCER national office I Washington, D.C.)

By semester's end, usually six to eight students change their majors to chemistry. Some students tell me that they were dreading their required chemistry course, but ended up liking the most among all courses. Students love having the material relate so clearly to issues that matter to them. Faculty who try this approach should expect receiving comments on their final evaluations such as these:

"I think it's pretty neat that I can actually do chemistry! This is my first chemistry class and never thought I'd be doing what I am now!"

"Best: You are extremely fun to learn from!

Worst: Not enough time. I want this class to be longer."

"My favorite thing about going to class is knowing that I have got my money's worth. The worst thing about this class is that there is only one a day."

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

A final benefit that comes with the SENCER community is the assessment help that the project brings to your teaching. The Student Assessment of Learning Gains, or SALG, is an assessment tool that has been developed with NSF funding and modified specifically to evaluate how helpful students find different forms of learning (http://www.salgsite.org/). One can also customize the form to include questions specific to the issues that one has selected to feature in the course. With a before and after question on the SALG survey, one can easily see that the course has made a difference in the perceptions of the class members. Table 3 shows the data from the 2007 pre- and post-SALG question regarding the pulp mill:

Table 3

	Pre-Course	*Post-Course*
It's an environmental nightmare.	68 (15%)	12 (4%)
More industries should use them as a model.	34 (8%)	257 (88%)
I haven't the foggiest notion.	345 (77%)	23 (8%)
	n = 447	n = 292

Clearly, the closed-loop aspect of the kraft pulping process appealed to their sense of sustainable ways to do business. Thus, an environmental issue about which many long-term residents of Missoula are still misguided was correctly evaluated and accepted by the beginning chemistry students at the end of the course.

Chapter 8

Stop, Look, Listen: Making a Difference in the Way Future Teachers Think About Science and Teaching

Carolyn M. Viviano,*,[1] Maria R. Alderete,[1] Catie Boarts,[2] and Meredith McCarthy[2]

[1]Loyola Marymount University, Los Angeles, California 90045
[2]Heal the Bay, Santa Monica, California 90401
***E-mail: cviviano@lmu.edu**

We draw on our experiences designing and implementing a SENCER course for future science teachers to discuss the benefits of an integrated and relevant community-based learning experience for future educators. Broad issues related to water and the environment form the core of our capstone course; students collaborate with environmental educators from a local non-profit environmental agency and teachers from area high schools in the design of service-learning projects that enable high school students to address environmental issues within their community. As a result, both groups of students strengthen their ties to the community and begin to appreciate the connection between environmental health and community health. The core principle of our approach has been to create sustainable, collaborative partnerships where all stakeholders are involved in the development process from planning through implementation and evaluation. By blurring the boundaries between formal and informal education, we have found that students are more engaged, they connect more effectively with the community and they begin to develop the tools they need to make science relevant to their own students.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

"I'm not going to college. I am going to be the best rapper that ever lived."

K.T., Generation Green

Generation Green

Beatriz and Ivan, two LMU students enrolled in our SENCER course for pre-service science teachers were responsible for establishing and leading the Generation Green club at our new partner school in Watts. The school offers youth and young adults who were unsuccessful in their local public high schools a chance to reclaim their education and earn a high school diploma. Beatriz and Ivan had been promoting the after-school club as an environmental group and were excited to connect with the students who came to the first meeting by introducing themselves, sharing their motivations for being there and asking the students to do the same. We never discussed what types of responses they expected going in but after hearing "it was an alternative to detention" from the majority of the students, they left the meeting disillusioned and concerned that no one would attend the next meeting. As Beatriz and Ivan reflected on the first Generation Green meeting in class, they realized that they needed to clarify their goals and find a way to connect with the students in order to engage them. Of course, they knew the theory but this experience forced them begin putting those ideas into practice; the rest of the semester was spent exploring what it means to be a teacher and making a difference to the six boys who formed the core of Generation Green.

Introduction

Every SENCER course is built around a complex civic issue or question that informs student thought and gives relevance to science content. The SENCER approach is very successful at inviting students to begin their own dialog with science by making science relevant to their lives and engaging them in the process of learning and discovery (*1*, *2*), however there is also an inherent value of SENCER in empowering students and enabling them to become engaged citizens. We have begun exploring the potential of this aspect of SENCER to change the approach of future high school science teachers to their mission. Pre-service science teachers are science majors who already recognize the value of a science education and who are excited about sharing their passion for science with others. We want to offer them the opportunity to develop the ability to foster connections between science content and issues that are relevant to their future students, most of whom will not become majors in STEM fields. We want to SENCERize the high-school science teachers. In order to achieve this we must connect pre-service teachers to: (i) high school students and teachers, and (ii) with appropriate non-profit organizations in their community and create an experience that enables the future teachers to begin to appreciate the value of community-based learning and explore their role as teacher/citizen. Our two semester capstone experience for future teachers, the SENCER Workshop Series, (hereafter referred to as the Workshop Series/Course) is designed to accomplish these goals.

A Rationale for SENCER in Pre-Service Science Teacher Education

David Burns has stated that the future of SENCER lies in reflecting on what we have learned from participant projects over the past ten years and using that knowledge in the service of national goals for improved STEM learning, workforce development, and the public good (*3*). To achieve these goals, we must reach beyond universities directly into the schools and the community. Recent reports have suggested that including SENCER courses in the science sequence for pre-service (K-8) teachers would improve teachers' attitudes toward and understanding of science (*4*, *5*). It would also increase their ability to connect science to the subjects that are traditionally given higher priority in the lower grades and their ability to stimulate students' interests.

We know that student's attitudes toward science are already developing in middle school (*6*). If we are going to produce future generations who are scientifically literate and civically active then we need to have high school teachers who excite curiosity about and reinforce interest in science, in contrast to the too-common reality that students who enjoyed science in middle school are turned off of science by their high school science experience (Viviano, unpublished results). It is essential that we provide future science teachers with more than content knowledge and pedagogical theory; we must emphasize helping them to develop the skills and abilities that will enable them to cultivate student interest in science. We need teachers who can provide intrinsic motivations that challenge, enrich and empower diverse groups of students to use science as a tool for change (*7*, *8*). We argue that including a capstone SENCER course in the curriculum for future science teachers is an important step toward achieving this goal.

> *"This class shaped my entire concept of teaching. I've been through education classes previously...But only now do I understand how education must be in the future"*
> (student, Workshop Series 2010)

> *"I will never assume that students know or do not know some information. I will incorporate their community into the classroom so that the students can better relate to the material we are learning. I will try to empower them to be advocates for what ever issue we are discussing."*
> (student, Workshop Series 2012)

Developing Scientific Teachers

It has been more than thirty years since Lortie coined the phrase "apprenticeship of observation" and suggested that traditional teaching practices persist as the result of the fact that every new teacher relies on his or her own experiences as a student when they begin to teach. The end result is that teachers perpetuate the teaching styles that they experienced as students (*9*). Most of our pre-service science students' science education has been a series of traditional lecture/lab classes where the teacher is the expert in the room and the focus is on what we know rather than how we know it. No matter that pre-service teachers may have received some instruction about alternative ways of teaching as part of their teacher training, the frame of reference that they have for evaluating their own teaching is still their own experience as students. Asking new teachers to change that frame of reference without giving them the opportunity to explore alternative ways of teaching is unrealistic (*10*). If we want to change the way science teachers structure their classroom we must first provide students with the freedom and opportunity to explore who they are as teachers and to think about teaching scientifically without the constraints imposed by specific content and methods courses and before they have developed habits that might be difficult to change. Integrating SENCER courses into pre-service science teacher education will enable us to support our students development into scientific teachers.

> *"There is not one thing that I would carry with me but my whole experience throughout the year. It was really a turning point in understanding what it means to be a teacher and how fill the role."*
> (student, Workshop Series 2012)

SENCER and Place-Based Education

David Sobel defines place-based education as the process of using the local community and environment as a starting point to teach concepts in subjects across the curriculum. Place-based education has been gaining momentum as a school reform initiative due to the fact that early results from schools nationwide have suggested that using the environment as an integrating context for learning in K-12 schools has a positive impact on learning and increases academic achievement. The benefits observed included increased test scores in all disciplines, decreased behavioral problems, increased student engagement and enthusiasm for learning and greater pride and ownership in accomplishments (*11*). In addition, students who are engaged in real-world learning experiences are more likely to connect with their community and develop a greater appreciation for the natural world (*12*).

Although SENCER is not necessarily place-based education, it can be. By definition, place-based education is local; students (and teachers) must begin by positioning themselves within their environment and their community. If we choose a civic issue that connects to the environment and has local impact, the SENCER course essentially becomes a place-based or community-based learning experience that connects science to students' lives. This is a powerful combination that enables future teachers to experience the positive effects of connecting science teaching with environmental education and service learning. As a result they will gain confidence in their own ability to create more meaningful work for their students and to become agents of curricular change within their institutions.

"I think it has given me the tools to redefine my teaching style, and work on how I will structure the class to be more comprehensible. I was also introduced to a new and great way of teaching. The community based learning project is a great way of teaching that I feel fortunate to have had experience with this."
(student, Workshop Series 2012)

"I will carry the aspect of service learning ... I would like to help implement more projects in other schools or just in my life."
(student, Workshop Series 2010)

The Workshop Model

Our overarching goal in creating a SENCER course for future science teachers was to provide each individual with (i) the opportunity to connect science to his/her community through an environmental lens and to their students' lives and (ii) to explore his/her own potential as a science teacher. We wanted to create an experience that was structured had a clear direction yet also the flexibility to be adaptable, thereby allowing students to become the architects of their experience. We also wanted the environment to foster critical thinking, creativity and deep learning. If we could provide students with the opportunity to rethink how science is taught as well as real-life experience teaching and working with high school students, then they would begin their teaching career with confidence and from a point of understanding. The Workshop Series is a year-long (two semester), project based course that has been created and continues to be refined as the result of a collaboration between faculty and staff at Loyola Marymount University, staff at Heal the Bay, a non-profit environmental organization dedicated to making Southern California coastal waters and watersheds safe healthy and clean, and teachers from two high schools in the Los Angeles area. This collaboration is essential to the viability, relevance and value of the course, both as an experience for our future teachers and a fruitful interaction for everyone involved.

Course Description and Expectations

The complex civic issue at the center of our SENCER course is community health through the lens of local water quality and watershed health. Water is an issue that resonates in Southern California where it has been used to transform nature and wield political power. Watersheds create natural boundaries that connect every individual to each other and to the ocean, however many people do not know what a watershed is and are unaware of the fact that their actions have widespread impacts on environmental and community health throughout the watershed.

Our rivers and creeks are incredible resources and they can be used to awaken the human connection to water. Each problem presents an opportunity for education and action. As community members are helped to understand the connection between community health and watershed health, our rivers become

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

metaphors for the communities that surround them and there can be incremental change in the behavior of the community with respect to the environment. The convenience of single use plastic bags now fades in comparison to the resources required to manufacture them, the blight created in the neighborhood if they are not disposed of properly, the habitat damage to the creek that runs through the neighborhood and the hazards they create for the ocean animals beyond, and individuals are able to make a better choice. Creeks and rivers, like the communities that surround them, can heal if given the opportunity and the resources.

The students enrolled in the Workshop Series are introduced to watershed education and issues through Heal the Bay's Key to the Sea Program, an environmental education program for teachers and students providing teacher professional development, standards aligned curriculum, and a hands-on learning experience at the beach/local aquarium. This introduces students to Heal the Bay and its staff and forms a platform for their own thinking about the importance of connecting scientific understanding to watershed health and the community. Heal the Bay continues to provide resources and support to the students throughout the year as they develop their projects. Ultimately students enrolled in the Workshop Series are expected to work collaboratively with high school teachers and students and Heal the Bay staff in order to: (i) conceive, plan and implement an environmentally focused service learning project and (ii) produce science curricula and instructional guides that can be used as a resource by teachers. Ideally the student-created materials will be incorporated into Heal the Bay's resources for future teachers and community educators and will be available on their website.

At the beginning of the first semester, students meet with the partners and are given an overview of the course objectives and philosophy. Partners share their motivations for participating in the project and ask students to share their own thoughts, expectations and concerns as they look forward to the upcoming year. This is followed by a discussion and reflection on community-based/service learning. These initial meetings are very important as they set the tone of the course and are instrumental in demonstrating to the students that they will be working within a supportive environment where their ideas matter. We acknowledge the scope and significance of the commitment we are asking of them but also make it clear that they will influence the direction and range of the project. All that happens over the course of the next two semesters is designed to provide them with the background, support and scaffolding that they will need to be successful.

An overview of the structure and logistics of the course is shown in Table I. We have found that the two semester model is essential to making the course work. Pre-service teachers make a commitment to becoming a consistent presence in a high school science class for most of the first semester. This enables them to develop a working relationship with the teacher, become comfortable in the classroom, learn about the culture and needs of the school and begin to get to know the students. The pre-service students start out as observers in the classroom, and progress to assistant when the teacher feels it is appropriate for them to take on that responsibility. The high school teachers agree to let the pre-service students teach at least one lesson during the semester; the topic, type and length of the lesson

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

is determined in collaboration with the teacher. These lessons are followed by a debriefing session with the teacher; tapes are subsequently reviewed and discussed in the college classroom. For many of the pre-service students this is their first opportunity to teach, and it is often a very eye-opening experience that changes the way they see themselves. By the end of the first semester they have learned a great deal about themselves as future teachers, have begun to identify their own strengths and challenges, and are in a position to begin working with high school students to conceive of, support and implement an environmental service learning project that addresses the issue of watershed health in a way that is meaningful to the students.

During the second semester pre-service teachers focus on working with a group of high school students to develop environmental service learning projects. We have found that this process is most successful when the group of high school students is small (10-15) and when the pre-service teachers work with the high school students during after-school club hours or an advisory period. This gives the pre-service teachers the freedom to explore their own teaching style while providing students with the background and guidance that they need to develop and implement their project. It also provides a less structured environment that promotes more genuine interactions between the high school students and their pre-service teacher. When we experimented with integrating the project work into a regular class, we found that the pre-service teachers were not able to take ownership of the work or make meaningful connections with the students. The projects essentially became the domain of the teacher and the pre-service students responsibilities were to provide background knowledge to the students. This had a marked effect on the pre-service teachers motivation, capacity to engage with students and their sense of accomplishment.

The most successful projects have resulted from collaborations between the pre-service teachers and the high school students, where the pre-service teachers have been able to assist the students in defining and developing a project that is driven by the students interests and concerns and takes into account the needs of the school and/or community. When this happens both groups of students are engaged and motivated and the end result is something that has immediate impact and enduring value. Examples of effective projects developed by students in the Workshop Series include: a storm drain painting project where student designs were painted on local storm drains in order to raise community awareness (figure 1 top); a water-wise campus vegetable garden that increased permeable space on campus and that could be used as a learning resource for future students (figure 1 middle); an after-school environmental club that will take up the mantle of raising campus awareness of conservation issues (figure 1 bottom). Each project was a significant logistical and experiential undertaking for our pre-service teachers and was their first step toward becoming a science teacher.

> *"Giving the students responsibility to act for change within their community is empowering"*
> (student Workshop Series, 2012)

Table I. The SENCER Workshop Series at a Glance

<table>
<tr><td colspan="2">Overarching Goals</td></tr>
<tr><td colspan="2">• Enable each student to grow as a teacher & to think about his/her role in a wider context

• Provide future teachers with the tools & experience needed to create content rich, active learning experiences for their students

• Promote life-long learning & encourage a deeper level of understanding and community involvement through partnerships</td></tr>
<tr><td>Semester 1</td><td>Semester 2</td></tr>
<tr><td>Experience: Weekly meeting at LMU regular attendance in high school class

LMU campus: Classwork/assignments that support discussion and evaluation of teaching, learning and high school work

High school: Observations, seminars with teachers & students (classroom observation and management, assessment) short teaching assignments (taped and evaluated)

Heal the Bay: Training days</td><td>Experience: Weekly meeting at LMU regular attendance in high school class

LMU campus: Classwork/assignments that support student teaching and projects

High School: Designing and completing science service learning projects with the high school students including teaching science content relevant to the project and necessary for students to become community educators

Field Trips: Determined by student interest and projects examples: Santa Monica Bay Aquarium, Ballona Wetlands

Community Connections: Determined by student projects</td></tr>
<tr><td colspan="2">Notes
• Pre-service student work at the high school transitions from a traditional classroom during the 1st semester to an after school group or advisory during the 2nd semester

• Heal the Bay involvement varies over the course of the 2 semesters; the type and amount of contact with the pre-service teachers varies with each project but is always significant. During the spring of 2010 Catie Boarts, a member of Heal the Bay’s education staff came to class each week to work with the students; education staff from the Santa Monica Bay Aquarium and the Speakers Bureau program worked with students in a variety of different capacities throughout the 2011-12 school year.</td></tr>
</table>

Figure 1. ***Student Projects.*** *(top) Two photographs of the storm drain painting project at Environmental Charter High School. Students designs of california native species were approved by the city and painted on four storm drains near the school – dungeness crab (left/ photograph by Jon Rou/LMU) and brown pelican (right). (middle) Students at Environmental Charter High School created a water-wise garden on campus (photographed by Jon Rou/LMU). (bottom) Generation Green students from Youth Opportunity High School designed and painted a mural to raise awareness on their campus (left); Generation Green students on a field trip to LMU (right) (quotation) Workshop student, 2010. (see color insert)*

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

In addition to being 'embedded' in a high school for two semesters, the students also complete classroom assignments that support their learning and provide a foundation for their work at the high school. Table II identifies key assignments designed to improve pre-service teachers' understanding of content knowledge, environmental literacy and teaching. The list is not exhaustive; it is intended only to give the reader a synopsis of the classwork and possibly serve as a guide for course development. Some of these assignments are short term, involving journal clubs to discuss relevant articles and research papers or participation in teaching seminars, whereas others continue through both semesters, such as writing a teaching philosophy. We have chosen assignments that are at the core of the course and that previous students have indicated were helpful. Two from the list merit special attention: the reflective journal and the student driven assignments. Reflection is an essential component of a SENCER course; the journal provides the space for each student to explore his/her experiences, to respond to them and learn from them. "Experience alone opens a door, but intellectual framing and reflection are required if meaning is to be made of the experience (*13*)." The journal provides students the opportunity to develop and refine their ability to derive meaning from their experiences through critical reflection.

At the beginning of the class, students are told that they can assign work to the class, including the professor and partners, if there is something that they feel is missing or simply needs to be addressed. For example, one student screened *Waiting for Superman* Davis Guggenheim's review of public education (*14*), others have assigned specific papers for the class to read and discuss. Although not all students have taken advantage of this opportunity, the possibility to have some agency over the class has a profound impact on student engagement.

Table II. The SENCER Workshop Series; Selected Assignments

		Specific Objectives		
Key Elements	***Comments***	***science content***	***science teaching and learning***	***environ-mental literacy***
Journal	Students keep a reflective journal for the entire two semesters which includes both free and prompted reflection exercises	√	√	√
CBL/SL Reading & Discussion	Students participate in a discussion and reflection of community-based learning/service learning		√	

Continued on next page.

Table II. (Continued). The SENCER Workshop Series; Selected Assignments

		Specific Objectives		
Key Elements	***Comments***	***science content***	***science teaching and learning***	***environ-mental literacy***
Science Standards Analysis	Students review, evaluate and discuss the national and state science standards and California's environmental principles and concepts	√	√	√
Teaching Philosophy	Students draft and revise their personal teaching philosophy over the course of two semesters		√	
Reading/ discussion	Students are assigned a variety of articles and papers that relate to environmental issues, science and teaching including place-based education	√	√	√
Empower-ment grant	Students apply for a service learning grant (up to $500) that they can use to help fund their environmental community-based learning project			√
Science lessons	Students prepare and teach science lessons and evaluate the results	√	√	√
Project booklet	Students produce a guide to their project that includes both science content and project guidelines	√	√	√
Student-driven assignments	These are discussed in the text and can connect to any of the three categories	(√)	(√)	(√)

Note: The classroom interactions that occur as the result of these assignments support learning goals that extend beyond the specific objectives listed here. This list is intended to provide the reader with examples of the types of assignments that are being used to ground the off campus experiences.

Student Learning Gains

The SENCER Workshop Course is the capstone course for students in our secondary science education program; it has been offered twice to a total of 6 students. We have used the SENCER SALG (Student Assessment of Learning Gains) instrument (*15*) to provide us with information regarding student learning and perceived value of the overall experience. The SALG is organized into the followings sections: 1, the overall response to the class; 2–5, the effectiveness of specific aspects of the course in helping student learning; 6 the adequacy of the support provided for learning; 7, improvements in understanding of specific content; 8 & 9, skills gained and attitudinal changes; 10, learning integration. [http://salgsite.org/]. The responses from students who have completed the course have been overwhelmingly positive and indicate that we are providing students with a valuable learning experience that they will carry with them as they move on with their teaching career.

Figure 2 shows the student responses to all questions in sections 1 and 6–10, which speak to the overall value of the course in effecting change in students' attitudes toward and understanding of teaching science and building students' confidence in his/her ability to teach and become agents of educational change. These data become more significant when taken together with the responses to short answer and reflection questions (Table III). Our initial results indicate that we are on the right track in terms of course design and implementation. As we continue to evaluate and revise the experience, we are hopeful that we will be able to provide a model for others interested in the value of SENCER in teacher education, specifically in the sciences.

> *"I'm confident that I will take with me the knowledge I gained through LifeWorks. I can't thank the whole team enough, the only way is to run and empower others as you have enlightened me."*
> (student Workshop Series, 2010)

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

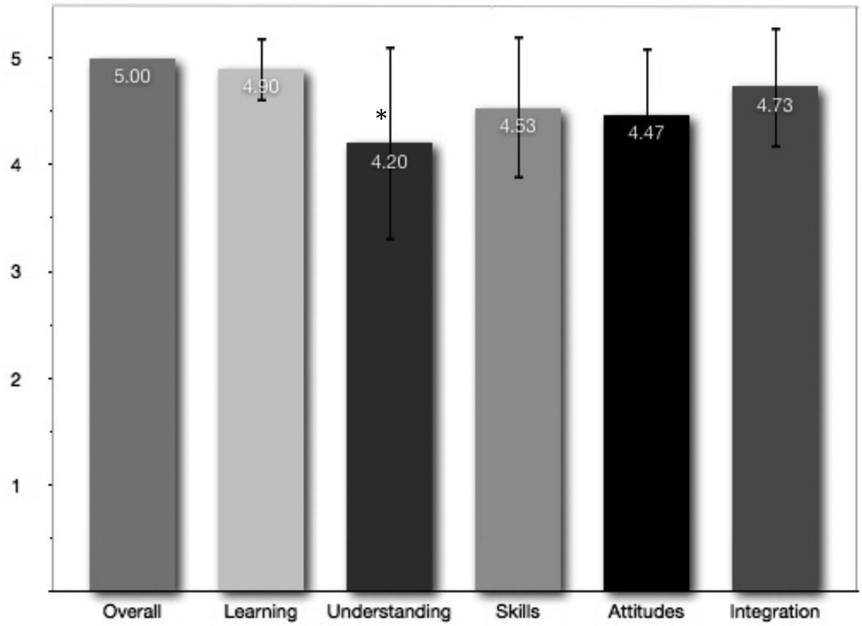


Figure 2. ***Student Assessment of Learning Gains in the SENCER Workshop Course for Pre-service Science Teachers.*** *These data were collected from the 6 students who have taken the course. The numbers in each category represent the average of combined student responses to all questions in a particular category. The number of questions in each category ranges from 3-9. The categories are defined as follows: the class overall, support for you as an individual learner, your understanding of class content, increases in your skills, class impact on your attitudes. Responses were made on a 5 point scale where 1 = no gains, 2 = little gains, 3 = moderate gains, 4 = good gains, 5 = great gain * The responses to questions in the "Understanding" section assess gains during the course; the lower mean was due to the low response of a single student who entered the course with a very strong background in environmental science.*

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Table III. Sample Student Comments

Overall	*"I am confident that I will take with me the knowledge I gained through LifeWorks. I can't thank the whole team enough, the only way is to run and empower others as you have enlightened me."* *"This gave me the empowerment and confidence that I needed to continue my teaching career. The support I received was amazing and truly impacted how I approach a lesson."*
Learning	*"My understanding of local water and CA water has broadened. I knew the main aspects of course, but it wasn't until I broke it down to a high-school level that the I actually wrapped my mind around the dynamics of our local water. "* *"When I think about teaching I now always think about the big picture of what I want the students get out of the lesson and take away."*
Under-standing	*"Students will be more inclined to care about an issue if they can connect it to their home."* *"Engaging the students is critical so that they feel connected to the problem."*
Skills	*"I have gained the skills to get things done... I believe I have also developed the ability to work with the high school students and create a project that was both fun to do but also educational."* *"I am more confident about teaching science to students. I more prepared to making (sic) big projects like the one we had happen."*
Attitudes	*"I feel confident in my ability to lead students through learning experiences in many circumstances (Just as GOOD, if not BETTER than most new teachers with credentials!) Just through this class, though that's quite a claim hah!"* *"I learned how important it is to explore the issues and to share these issues with people because so few people believe or know there are huge problems. ...I have started to become an activist."*
Integration	*"As the result of taking this class, I've begun to examine the methods and style of my instructors."* *"... I feel that a lot of what I'm saying can be summed up into a sweeping category of leadership and management."* *"Countless things, actually, but primarily a sense of empowerment of myself."*

A Scientific Endeavor

"In the field of observation, chance favors only those minds which are prepared." Louis Pasteur, 1854 (*16*) Alexander Flemings' discovery of penicillin in 1928 is often used to illustrate this idea to introductory biology students. The popular version of the story is that Fleming, who was studying the staphylococcus bacterium, arrived in the lab one morning to find that some of his bacterial culture plates were contaminated with mold. Rather than simply discarding them, he noticed that the mold colonies were surrounded by a bacteria-free halo and

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

become intrigued by the phenomenon. He was no doubt aware of earlier reports by several others that mold seemed to inhibit bacterial growth and thus was inspired to perform experiments that demonstrated that mold extract prevented growth of staphylococci, even when diluted 800-fold. He called the antibiotic substance penicillin. In scientific research, the unexpected happens; it was Fleming's ability to recognize a chance finding and respond to the situation that led to his success. He was observant and remained attentive and curious.

Creating and implementing this type of SENCER course for future teachers has much in common with opening a scientific inquiry. Certainly, preparation and planning are essential to success but do not guarantee a successful outcome; they simply enable you to begin the work on solid ground and within a specific framework. Once the course (an experiment) has begun, it takes on momentum and develops a character of its own in response to the interests and needs of the students and the high school partners. The key to success is to have the ongoing willingness and ability to evaluate and reformulate one's goals and expectations as new information arises and, most critically, to invite the students to take part in the process of scientific teaching. It is important that the students understand that the course is a work in progress, that it is the beginning of an inquiry that will continue to generate new ideas and questions and that may take a path that deviates from the original. This is a little unsettling for them initially, especially if the majority of their experience of teaching has been in a teacher-controlled classroom where there is a linear progression of ideas and content as outlined in the syllabus. Once they realize that the pedagogical flexibility provides them the opportunity to influence how things happens in class and contribute to the discourse, and that you are there to support and work with them, their anxiety dissipates and they begin to engage in the process. These students are naturally observant and curious, we need to provide an environment that supports and encourages that.

Our SENCER course is designed to be a capstone experience for future science teachers who have completed most of their content classes. By the second semester of the Workshop, our classroom has become a lab where students experiment with teaching. As the pre-service teachers work with small groups of students to define and implement their projects, they explore how to engage and motivate students, how to make content relevant and accessible, how to accommodate different student experiences, and how to manage students' work on the project. At times, this process will get messy and student's emotions fluctuate in response to their perceived successes and failures. Successful laboratory scientists learn to accept this messiness as a natural part of the process of learning and discovery; we use it to engage our pre-service teachers in critical reflection, discussion and re-evaluation of their work. It is important that our pre-service teachers begin to see the process of teaching as investigative, as an exploration of questions through trial and error, critical evaluation and the sharing of ideas and information.

Let's return to the Generation Green story at the beginning of the chapter: Beatriz and Ivan went into Generation Green with a specific plan that made certain assumptions about the motivation of the students attending the first meeting and they left somewhat disheartened—concerned that the group was not going to come together. Although this was a potentially negative situation for them, our

SENCER class is designed to absorb these potential set-backs and turn them into positive learning experiences through deep thinking, critical evaluation and reflection, As a result, they began to rethink their approach, initiated discussions with the other SENCER students and partners about how they might engage these students, and ultimately reached their goal of increasing their students' environmental literacy. In retrospect the first Generation Green meeting was ideal, compelling Beatriz and Ivan to develop habits of critical reflection at a very early stage in the course and become keen observers of their students. As they gained confidence they began to make suggestions about how to change particular lessons in the curriculum they were using to make them more relevant to the students; we encouraged them to implement many of these changes and to evaluate the results. The students in Generation Green began to see the relevance of what they were learning, to understand some of the environmental issues facing their community and to recognize their power to make a difference. They designed and painted a mural, wrote an anthem and hosted the Generation Green fair to share what they had learned with the rest of the school and to recruit new members.

As for Beatriz and Ivan, the design and inherent flexibility of the course enabled them to take ownership of their work and to begin to connect theory with practice. They began to develop a scientific mindset toward teaching; they are able to learn from mistakes and have gained confidence in their ability to make informed decisions about teaching science content. They have completed a first pass through Shulman's Table of Learning—engagement and motivation, knowledge and understanding, performance and action, reflection and critique, judgement and design, and finally, commitment and identity (*17*)—and are poised to fully engage their professors, mentor teachers and students as graduate credential candidates. In essence they have made a commitment to teach.

An excerpt from Beatriz's Final Reflection:

> "...This has definitely been an adventure. I was not too sure of what the ending result was going to look like, but I always knew that it was going to be a good one. I don't have words to describe how much this class changed my life. I had the idea that I wanted to become a teacher after graduating college, but I was never sure. Being part of this class and working with Generation Green students assured me that I made the right decision. I was actually really nervous at the beginning of the class because I was not used to being part of a class that had so much flexibility. The thought of not being able to control (the student experience) and (not) have (sic) a concrete guide telling me what needed to be done scared me. Looking back, that was probably the best part of the class. Shaping my own experience as I worked with Generation Green students allowed me to grow personally and academically. I will never forget the first time I taught a lesson plan. It was a nerve wracking experience, but I can now say it was a learning experience too. ...

Recognizing Success

SENCER work, like all service learning, challenges us to re-evaluate and broaden our definition of success to include intangible as well as tangible gains. The 'tangibles' are relatively straightforward to assess and represent immediate, short-term successes. It is gratifying to see a pre-service teacher demonstrate a more nuanced understanding of a particular science topic, or become better at eliciting student response in the classroom. However, the real value of a SENCER course for future science teachers is in the process rather than the product and in our ability to shepherd students through the uncertainty at the core of the course and have them emerge as more confident, engaged individuals, teachers and citizens. These types of gains are not easily quantifiable and are often not necessarily immediately apparent.

Clayton and Ash (*18*) have astutely equated the progression of a service learning course with riding a wave of dissonance that moves from enthusiasm to uncertainty, confusion, insecurity and frustration to increased effectiveness, creativity, greater openness to challenge and risk, deeper self-awareness and a stronger sense of personal responsibility. Our SENCER course is no exception; as we ride that wave *with* our students, we must keep sight of the fact that success lies in keeping them afloat, helping them to understand and value the process of learning and discovery and giving them the confidence and skills to become life-long learners. This is no easy task because we are both the architects of the experience and participants in it. As we push our students and ourselves outside of our comfort zones, we create a space alive with uncertainty and possibility. How we inhabit that space and how well we support the others in it is what creates the possibility for transformation in our students and in ourselves.

The Power of Partnership

The success and strength of the Workshop Series lies within the partnership that created and continues to shape it. Although the work originated at LMU with the idea of creating a capstone experience for future science teachers, the intellectual contributions of all of the partners and the resources provided by their respective institutions made it what it is. The academic environment at LMU provides a framework for discourse between faculty and staff who have science and service learning experience and pre-service science teachers; the high school partners provide mentor teachers (both science and non-science), a meaningful context for the work and access to high school students; Heal the Bay is an environmental non-profit organization that defines our civic issue by providing a point of view, a wealth of resources and staff with expertise ranging from education to advocacy to research. In addition Heal the Bay gives the project long-term sustainability and relevance beyond the classroom. As a non-profit organization, it has a ongoing role in the community and represents a resource for students involved in the project as they move on with their lives, both as teachers and as citizens.

The collaboration results in a rich, meaningful experience for the pre-service teachers that has an impact beyond the university. The pre-service students help facilitate projects at their high school placement and provide high school students with a direct connection to college and the variety of opportunities that arise from that relationship; this is especially valuable for students in under resourced schools. Heal the Bay grounds the student experience and strengthens and expands their influence through the pre-service teachers.

As we develop SENCER projects that bring the college classroom into the community, we must also invite the community into the classroom. To do this productively, we must cultivate collaborative relationships with partners whose goals are compatible with our own and engage them in the process of course development. Partners who are asked to share in the processes of creating, implementing and evaluating a course will become more invested in the outcome, and the students will end up with a more vibrant course that will evolve and remain relevant. The expertise and ideas that come from the community experts help shape the student experience and foster a learning environment for everyone involved. As SENCER moves to the next level, we are in favor of including a statement on partnership in the SENCER ideals and creating a summer institute workshop that addresses how to create strong and sustainable partnerships.

Impacts and Connections

One of the most gratifying things about this work and the partnership that inspired it is the network that has been created and the broad ranging impacts that have resulted from a single course and only a handful of students. When the course is in session, the focus is necessarily on day-to-day management and student progress. However when we are able to take a step back to assess and evaluate, we begin to recognize all that is happening as a result of the students work. In our view, the untapped power of SENCER is in the space around the course, in the connections and relationships that develop, in the community changes that take place, in the transformation of individuals lives that begin to happen, quietly, as a result of the collaboration that built the course (Figure 3).

We began this chapter with a quotation from K.T., one of the Generation Green students who expressed no interest in the environment or college. His goal was to become the “best rapper that ever lived”. Nevertheless, he remained a member of Generation Green; it was, after all, better than detention and snacks were provided. Fast forward 15 weeks: K.T. conceived the idea for and wrote *Change*, an anthem for Generation Green and performed the work for students, faculty and staff at the Generation Green school fair. He also began seriously considering college and has signed up for his school’s 10 college tour. K.T. has decided that college is something that makes sense, perhaps majoring in music; it might even help him become the best rapper that ever lived...

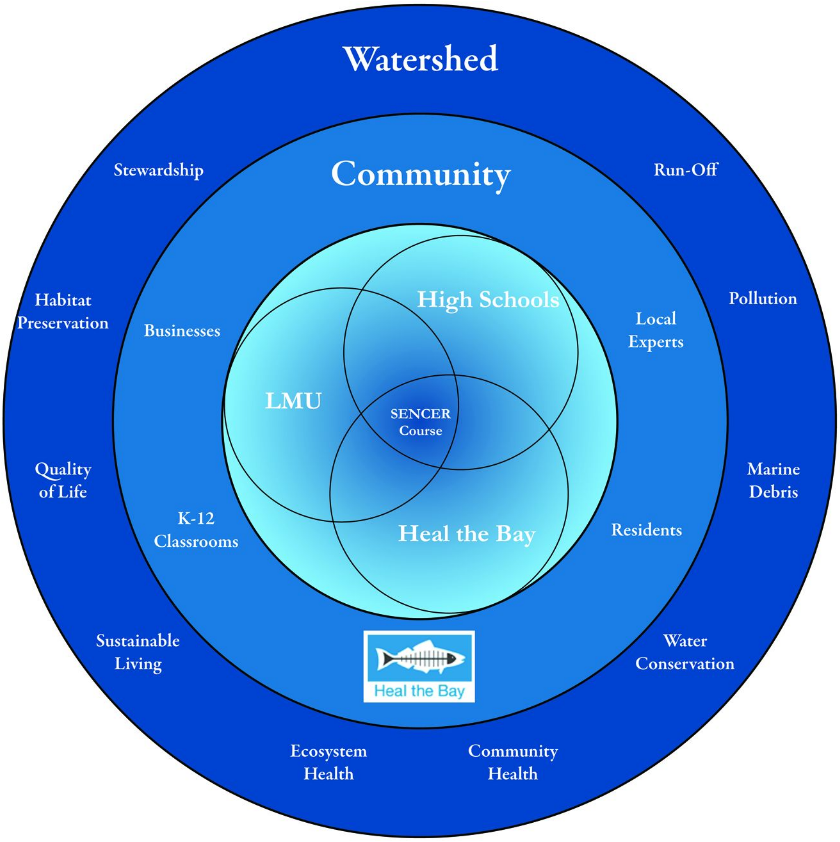


Figure 3. ***Impacts and Connections.*** *Our SENCER course (center) is the result of the collaboration between partners from post-secondary (LMU) and secondary (Youth Opportunities and Environmental Charter High Schools) academic institutions and an environmental non-profit (Heal the Bay). The students (both college and high school) and their projects have had an impact on the community (middle ring) as a result of the relationships that have developed in support of the projects and on the environment as individuals begin to change their behavior in an effort to improve watershed and community health (outer ring). (see color insert)*

Our discussion here has focussed primarily on the rationale behind and the potential benefits of creating relevant community-based learning experiences for our future science educators. However, we wish to end by acknowledging that the high-school students are an integral part of this project and we are only beginning to understand the impact that these two groups of students (college and high school) have on each other. We will let the students speak for themselves: Beatriz in her reflection on the Workshop Course and K.T. introducing the debut performance of Change to the crowd at the Generation Green fair.

> *Generation Green was more than I ever expected it to be. It was more than just an after school program or a grade. Ivan and I were able to teach the students about (resource) extraction, production, distribution, and disposal, as well spark some passion about environmental issues. All of this would have never been possible without your constant guidance and support. Youth Opportunities High School has many students who are not reaching their full potential because they are not being motivated. I wanted to be that for them, motivation and support. ... Overall this was a great class and I am sad to let them (Generation Green) go.* (BA, 2012)
> *"This song is called Change. The message of the song is that everybody want (sic) the world to change; we all want to change our lives. We all complain about changing this and that, but we can't change the world 'till we change ourselves."* (K.T., 2012)

Acknowledgments

We would also like to express our appreciation to all of the individuals who have been instrumental to making the Workshop Series a reality: Sara Laimon for her early contributions to the Workshop Series and all of her efforts to invigorate the work at Environmental Charter High School. Matthew Morrissey (Environmental Charter High School) for his insight and inspiration throughout the process and for valuable mentorship of our future teachers. Jonathan Yeh (Youth Opportunities High School) our newest teacher/mentor for inviting students into his science classes and for his support with the development of Generation Green. Tara Treiber, Melissa Aguayo and Edward Murphy (all from Heal the Bay) for the support and mentorship provided to the 2012 Workshop Class. And to Jenni Taylor (Environmental Charter High School) and Jessica Hutcheson (Youth Opportunities High School) for making our high school partnerships possible. We would like to thank Dr. Kevin Griffin for critical reading of the manuscript. This work has been supported in part by a SENCER sub-award [NSF's Division of Undergraduate Education CFDA number 47.076, under award number 0717407], student grants from LMU's Center for Service and Action Riordan Empowerment Fund, and a Community Service Grant from LMU's College of Science and Engineering.

References

1. Ballou, J. Reshaping How Educators View Student STEM Learning: Assessment of the SENCER Experience. *Science Education and Civic Engagement: An ...* **2012**, *4*, 27–36.
2. Carroll, S. *SALG Results Show SENCER Faculty Achieve in Raising Higher-Order Learning Gains*. http://serc.carleton.edu/sencer/newsletters/61795.html.
3. Burns, W. D. *SENCER in Theory and Practice: An Introduction and Orientation*, 2010.

4. Fink, M. Preparing Future Teachers Using a SENCER Approach To Positively Affect Dispositions Toward Science. *Science Education and Civic Engagement: An ...* **2009**, *2*, 14–21.
5. Utz, A. H.; Duschl, R. A. SENCERizing Pre-service K-8 Teacher Education: The Role of Scientific Practices. *Science Education and Civic Engagement: An ...* **2010**, *2*, 27–35.
6. Tytler, R.; Osborne, J.; Williams, G.; Tytler, K.; Cripps Clark, J. *Opening Up Pathways: Engagement in Science, Technology, Mathematics and Engineering (STEM) across the Primary-Secondary School Transition* **2008**, *29*, 2008.
7. Barton, A. C. *Teaching Science for Social Justice*; Teachers College Pr, 2003; p 197.
8. Markow, D.; Martin, S.; Comey, G.; Zwanziger, E.; Kim, A. *The National Survey on Service-Learning and Transitioning to Adulthood*; Harris Interactive: New York, 2006.
9. Lortie, D. C. *Schoolteacher: A Sociological Study*; 2nd ed.; 1975. press.uchicago.edu.
10. Kennedy, M. M. *Teaching as the Learning Profession: Handbook of Teaching and Policy*; Darling-Hammond, L., Sykes, G., Eds.; msu.edu: San Francisco, 1999; pp 54–86.
11. Lieberman, G. A.; Hoody, L. L. *Closing the Achievement Gap*; Using the Environment as an Integrated Context for Learning; Science Wizards: Poway, 1998.
12. Sobel, D. *Place-Based Education: Connecting Classrooms and Communities*; Nature Literacy Series; The Orion Society: Great Barrington, 2005.
13. Palmer, P. J.; Zajonc, A.; Scribner, M.; Nepo, M. *The Heart of Higher Education: A Call to Renewal (Jossey-Bass Higher and Adult Education)*, 1st ed.; Jossey-Bass, 2010; p 108.
14. One of our partner schools has a portrait of Geoffrey Canada in the hallway. This sparked a discussion among the class that prompted one student to comment that everyone should be required to see Waiting for Superman. As a result, that student prepared a list of discussion questions that were handed out to the class before we watched the film; he then led a post film discussion which culminated in a proposal to have the class collaborate with LMU's future teachers club to co-sponsor the film and lead a post-film discussion.
15. Carroll, S. Engaging Assessment: Using the SENCER-SALG To Improve Teaching and Learning. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 149–198.
16. Peterson, H. *A Treasury of the World's Great Speeches*; Simon & Schuster, 1965; p 469.
17. Falk, B. A Conversation with Lee Shulman—Signature Pedagogies for Teacher Education: Defining Our Practices and Rethinking Our Preparation. *The New Educator* **2006**, *2*, 73–82.
18. Clayton, P. H.; Ash, S. L. Shifts in Perspective: Capitalizing on the Counter-Normative Nature of Service-Learning. *Michigan Journal of Community Service Learning* **2004**, *11*, 59–70.

Chapter 9

Formal/Informal Science Learning through Civic Engagement: Both Sides of the Education Equation

Alan J. Friedman[1] and Ellen F. Mappen[*,2]

[1]Consultant for Museum Development and Science Communication, New York, New York
[2]Senior Scholar, National Center for Science and Civic Engagement, Washington, DC
[*]E-mail: ellen.mappen@ncsce.net

The SENCER-ISE project, supported by the National Science Foundation and the Noyce Foundation, sought to explore the potential for building long term collaborations between undergraduate science education institutions and informal science education organizations such as science centers, museums and the science media. The pilot project developed some promising approaches, while clarifying the barriers to be overcome in crossing the higher education/informal education divide.

Introduction

Education in America has tended to be divided into distinct, largely independent systems, including K-12 and higher education (HE) and within higher education, 2- and 4-year colleges and undergraduate, graduate, post-doctoral programs. There is also the broad area of informal science education (ISE), which includes after school programs and the ideal of lifelong learning. The separation between these segments often leads to problems, with undergraduate colleges complaining that the K-12 system sends them underprepared students, the K-12 system complaining that teacher colleges send them new teachers unprepared for the realities of the system, and afterschool and ISE operating largely independently of everything else. There is an attractiveness to independence, but there are also penalties in lost opportunities for making use of each system's

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

particular strengths, in the duplication of effort, and in leaving some learners lost between the systems.

The SENCER-ISE project, supported by the National Science Foundation and the Noyce Foundation (*1*), sought to explore the potential for building long term collaborations between undergraduate science education institutions and informal science education organizations such as science centers, museums, and the science media. The focus was to explore, primarily at an invitational conference, whether working together we could develop initiatives (including curriculum and programs) to increase interest in science study and enhance public understanding of science so that those who did not become scientists could become life long self-directed learners in issues involving science. The pilot project developed some promising approaches, while clarifying the barriers to be overcome in crossing the higher-education/informal education divide.

SENCER-ISE is an outgrowth of the signature program of the National Center for Science and Civic Engagement, SENCER (Science Education for New Civic Engagements and Responsibilities). The SENCER initiative's primary focus is the improvement of undergraduate teaching and learning through the framework of civic engagement. Its goals are to get students interested in science, technology, engineering, and mathematics (STEM) courses, while helping these learners connect their learning to other disciplines and to "strengthen their understanding of science and their capacity for responsible work and citizenship." Over 430 college and universities and other educational agencies and community-based organizations and more than 2,000 educators, administrators, and students have been involved with SENCER since its inception at the beginning of the 21st century. At least 600 courses have been designed or revised, with over 40 course models offered on line for the larger educational community (*2*). SENCER's approach impacts K-12 education through the work of pre-service faculty. In recent years, another initiative of the National Center has undergraduate faculty and students connecting with community-based organizations and informal science education facilities in the Great Lakes region.

While SENCER faculty have developed some partnerships with informal science educators and institutions, an attempt to bring together undergraduate science faculty and informal science educators across the interdisciplinary and institutional divides of these sectors has been limited, both within SENCER and beyond. Most interactions that we are familiar with occur at the K-12 level and not in higher education (*3*) In a summary of discussions organized by Public Agenda about collaborations between informal science education entities and higher education institutions, only enhancing connections with teacher education programs are noted (*4*).

Among the potential complementary aspects of higher education and ISE are the attention of ISE to strands of learning in the affective domain, while HE tends to focus primarily on the cognitive domain. While the distinction is not at all new (*5*), the differences between the attention paid to affective domain outcomes in formal and informal learning were recently recalled when the National Research Council's report on ISE in 2009 found it important to add two affective domain strands, one on motivation and interest, the other on identity as a science learner, to the four cognitive strands of the NRC's 2007 report on formal education (*6*, *7*).

In this respect, SENCER already had a sympathy with ISE because one major objective of SENCER is to increase undergraduate interest in taking science courses, by looking for instances in which civic engagement with local issues provides motivation for student learning. A recent analysis of student responses to the SENCER course evaluation instrument (SALG, or Student Assessment of Learning Goals) noted upward trends for faculty pedagogical goals, including student changes in attitudes towards science (*8*).

The goal of this chapter is to provide, especially for undergraduate educators, a general perspective on the benefits of collaborations between the realms of higher education and informal science education by discussing results from a conference which brought together HE and ISE professionals to explore the potential of such partnerships. The chapter examines the premise that despite different organizational and reward structures and seemingly different audiences, collaborations between formal institutions of higher education and informal science initiatives can contribute to knowledge development for learners of all ages. The authors will examine the role that the framework of civic engagement plays in curriculum or program development, discuss briefly SENCER-ISE as a preliminary case study in the process of developing partnerships, provide examples of the types of potential collaborations that can be developed, and examine the mutual benefits of such collaborations for the entire educational community.

SENCER-ISE: Developing Partnerships between Informal and Formal Higher Educators and Institutions

With the belief that a focus on civic issues and engagement could provide a bridge between these communities to develop strong educational partnerships, the National Center convened, with funding from the National Science Foundation and the Noyce Foundation, SENCER-ISE, an invitational conference in March of 2011 (*9*). Attendees included representatives from the SENCER higher education community and informal science educators from 19 states, the District of Columbia, Canada, Chile, and Israel. Conference participants "concluded that a shared focus on contemporary issues of civic consequence" would lead to "productive collaborations, achieve STEM learning goals and ... greater civic engagement," along with creating a "science-enabled citizenry" (*10*).

As an introductory exercise at the March 2011 conference, the participants started with the question "In the next 2-3 years, what are ways we could use civic engagement to achieve our educational goals?" (*11*). In the ensuing discussions, it became clear we were talking about a broad framework that could be applied in different ways, either as a means to the end of learning science through the study or examination of complex, unsolved civic issues (favored by the undergraduate faculty in attendance), or as an end in itself to bring about "positive change in the community," through "science-based decision making" and participation (preferred by the informal science educators present). How science is delivered by the different communities then became a thread throughout the discussions, which included activities on envisioning steps to develop "science-enabled citizens," obstacles to collaborations, partnership opportunities, and emerging strategies (*12*). In the end, there was consensus that the March meeting was just the first step for the SENCER-ISE initiative (*13*).

It should be noted that civic engagement means more than creating opportunities for service learning for undergraduates or citizen science activities (such as measuring levels of rain water or counting the bird population) for people of all ages, although those examples are ways to increase understanding of and participation in science. In general though, a broader definition of civic engagement in science encompasses an understanding of societal problems and how science can help citizens ask the necessary questions and find solutions to problems.

The Two Sectors

In a previous article (*14*), the authors discussed the differences between the two communities in terms of structures, audiences served, relationships of these audiences to the professor/exhibit designer, and age group. For example, formal K-12 education is normally compulsory, curriculum-based, teacher-directed, and age specific. This is similar for undergraduate education. Informal science education, on the other hand, is voluntary, based upon personal interest, self directed and life long. Assessment practices are different, as there are not tests or grades given when students/adults visit science museums or zoos, watch a science program on TV, or become engaged in citizen science programs.

Neither sector is monolithic. Formal higher education includes two- and four-year colleges/universities of varying sizes that offer a range of degrees ranging from associate to doctoral degrees, minors and certificate programs, and different degree options. The informal field covers a wide range of institutional types and approaches as well. A 2008 "landscape" study sampled 13 different communities that included educators from science centers and natural history museums, zoos and aquariums, media, parks and gardens, and after-school programs (*15*).

Although there are differences between and within these two realms of education, there are also commonalities in focus and in theoretical underpinnings between informal science education and higher education as represented by the SENCER faculty. In the earlier paper, the authors postulated the idea that the strands of informal science learning for participants (developing interest in science, understanding science knowledge, engaging in scientific reasoning, reflecting on science, engaging in scientific practice, and identifying themselves as individuals who both learn and use science) are not dissimilar from the SENCER Ideals, concepts that provide the basis for SENCER practice (*16*). These ideals encourage faculty to start with matters of interest to students that allow the latter to put scientific knowledge and the scientific method to use, begin with an intellectual project that is practical and engaged, extract from immediate issues the larger lessons of the process of science, and locate the responsibility of discovery in the work of the students. (*17*, *18*).

While there are different models of possible partnerships between these sectors, two existing combinations are the Portal to the Public program at the

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Pacific Science Center (*19*), which brings undergraduate faculty to the floor of a science center to develop and to practice public communication skills, and the Communicating Climate Change project from the Association of Science-Technology Centers (*20*), which brought together 12 research institutions with 12 science centers to create Citizen Science projects for public participation.

At a follow up SENCER-ISE meeting in November of 2011, a number of potential and nascent partnerships were presented, including:

Arkansas State University, Arkansas Fish and Game Commission, and the Trout Nature Center envision a project that aims to increase the interest and scientific knowledge of kids in the 10-15 year-old age range and their parents through their interest in fishing. They plan to hold a series of one-day workshops at their field stations (all have aquatic components) that will educate the kids and their parents about the ecosystem issues, ecological interactions between fish and other species, and how this affects their feeding patterns. There will be follow-up sessions online to see how any interest and knowledge gained changes over time.

University of Maryland Center for Environmental Science and the National Geographic Society are exploring efforts to support citizens and K-12 students in studying and addressing local and regional environmental issues using an online digital mapping and analysis tool developed by National Geographic (FieldScope). They are interested in examining how this tool can be used to support and enhance different types of existing citizen science and related projects—especially those that link citizens and students to environmental science research and resource management. For example, this online visualization tool could be used for entering data, mapping and analyzing datasets, sharing conclusions, and exploring new questions and solutions. They would also like to explore how best to support leaders of these diverse efforts in integrating this tool into their existing education programs and are particularly interested in expansion of this Internet program to mobile devices to broaden its application and accessibility.

Longwood University and Clean Virginia Waterways want to build a strategic partnership based on the development of a Center for Excellence in Environmental Education and have a leadership role in environmental education in Virginia. They would provide new opportunities for students to develop as citizen leaders, support educational efforts for K-12 students in selected regions of the state, and engage citizens in learning about the Chesapeake Bay watershed's environmental issues.

Benefits to Collaboration

As envisioned by the National Center and the participants in the SENCER-ISE project, there are multiple benefits to developing partnerships like these between the HE and ISE sectors, including:

- *Faculty at the higher education institutions* will learn skills in communicating with the public (and even their own students) through their partnerships with ISEs, allowing the faculty to advance their own broader impacts. Understanding more about how informal science educators attract and retain their audiences, which can vote with their

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

feet, will help faculty attract and retain non-science majors. *Portal to the Public* provides strong evidence for how much faculty can learn from an ISE, and how highly the faculty come to value their associations with ISEs (*21*).

- *ISE staff* will develop ongoing relationships with faculty at the higher education institutions. Instead of working with researchers on a more typical once-a-year advisory committee meeting, they will develop deeper trust and understanding, resulting (we hypothesize) in the ISE's staff being more engaged with current research, engagement that they can use in their own organization's work.
- *New institutional partnerships* beyond the individual students, the public, faculty, and ISE staff, will be built. These new institutional links possess high potential for generative collaborations strengthening a continuum to support lifelong learning. Individuals in both higher education institutions and ISEs are always in flux, but we hypothesize that institutional relationships between these education organizations can be sustained if the mutual benefits are demonstrated to be sufficiently valuable over a sufficiently long period of time.
- *Undergraduate students* will learn more STEM content and how to explain that content to others. SENCER has clearly demonstrated that using civic engagement with STEM-related issues brings more undergraduates into science courses and enthuses them about learning science. We have persuasive evidence that the SENCER approach helps college students achieve these intellectual and affective outcomes. A recent study based on SENCER faculty responses shows the type of "21st Century" skills that are learned in SENCER courses. These faculty believe their students can make connections between science and civic problems, make interdisciplinary connections, and identify scientific problems and questions (*22*).

  SENCER's attractiveness for undergraduates will be further enhanced, we hypothesize, by having public involvement through the ISEs. It is great to learn for your college degree, to please your peers and parents; but how much more exciting to share what you are doing with the public through exhibits and presentations at science centers, where tens of thousands of people can see what you are doing on STEM-related issues that matter to the public.

  For undergraduates, learning how to explain their work to the public enhances the students' own learning (you do not know what you know until you try to teach it). "Explainer" programs at hundreds of science centers around the world, and internships for college students at museums, media organizations, and community organizations such as after-school providers demonstrate the popularity and value of undergraduate involvement with the public. Civic engagement adds to these opportunities for involvement for large numbers of undergraduates, who, we believe, will retain longer-term involvement with public education, as demonstrated by longitudinal evaluations of programs like the Science Career Ladder at the New York Hall of Science (*23*).

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Graduates who do not major in science or another technological field will see also that they can turn to ISE when science questions arise after they complete their undergraduate studies.

- *Publics served by ISE organizations* will be attracted to learn STEM by the new civic engagement activities that the ISEs present and in which the ISEs offer participation opportunities to the public. We see strong evidence for this in the extraordinary growth of citizen science activities, which now involve millions of people a year. Citizen science is new for the ISE community however, with C3 being a pioneering effort to spur citizen science at twelve science centers. SENCER-ISE has learned deeply from C3's successes and problems. SENCER-ISE, by building ongoing, more equal partnerships between higher education and ISEs, will result in the ISEs being able to attract more public participants for longer periods of time, and will allow even non-citizen-scientists to appreciate and to learn about STEM through the important civic engagement projects presented by the ISEs for their audiences.

The Challenges to Collaboration Across the HE-ISE Divide

There is a substantial literature of survey findings, case studies, and advice on the formation for successful non-profit partnerships (*24–31*). Much of this literature discusses non-profits broadly, but many analyses and case studies focus specifically on ISE organizations partnering with higher education and research institutions. Essentially all of the literature and case studies we reviewed described a similar list of the specific challenges to forming and sustaining non-profit partnerships. Five of these challenges are directly relevant to SENCER-ISE:

- Non-profit partnerships are almost always more difficult to establish and sustain than the partners imagine they will be at the time a proposal is written. There is rarely enough thought and time given to forming partnerships before the proposals are written or before work begins. Initial responsibilities, decision-making prerogatives, and commitments from both sides need to be clearly defined well before the work plan is underway. Some flexibility must be expected and negotiated as conditions change.
- The differences in cultures between ISE organizations and research or higher education institutions are significant but rarely accounted for initially in forming partnerships. These differences can lead to misunderstandings and disappointments throughout the run of a partnership. For example, participants from higher education institutions are subject to very different constraints than those of the smaller, more nimble, but less well endowed ISEs. Both sides need to appreciate the positive and negative consequences of these differences. This takes time visiting each other's operations and understanding their values and limitations.

- Time and other resource commitments must be defined and agreed to in writing at the beginning. The absence of these written commitments is a common cause of friction.
- Institutional vs. individual commitments to a partnership produce very different outcomes that are often not appreciated at the beginning of a relationship.
- Organic relationships can lead to sustainable partnerships, while ad hoc partnerships rarely do. Organic relationships are distinguished by goals that meet key institutional mission needs of both partners, each partner having mutually-appreciated strengths the other does not, and a consistent process of communication and decision making.

What We Learned from SENCER-ISE

The project evaluation by Randi Korn & Associates (*32*) found:

> …new learning and perspectives resulted from conference participation; about three-quarters of interviewees said the conference had created an awareness of the value of the other sector, empathy for the challenges the other sector encounters, and/or concretized potential opportunities for collaboration between the two sectors. And, the remaining one-quarter of interviewees said the conference had confirmed and reinvigorated an existing belief that collaboration among the two sectors is a valuable endeavor.
>
> Encouragingly, findings show that there is much consensus between the two sectors when considering how best to collaborate around civic engagement in science, as most responses to interview questions represented equal numbers of those from ISE and SENCER; and initial collaborative steps have been taken by some interviewees. As such, findings demonstrate that the SENCER-ISE conference successfully achieved its two main goals of bringing ISE and SENCER professionals together to discuss civic engagement in science and inspiring ideas for collaboration between them. The challenge now is to help participants continue and build on the relationships and momentum that were started at the conference.

Continued discussions by SENCER-ISE staff, and the follow up meeting held in November 2011 with five newly-formed teams of HE and ISE professionals, all inspired by the earlier conference and including new potential partners who had not attended the earlier conference, confirmed that barriers to getting these partnerships underway and sustaining them were essentially those raised at the conference and identified by the Korn & Associates evaluation:

> First, findings suggest a continued need to build awareness of the value of using civic engagement as a platform to advance science understanding,

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

including what each sector brings to a potential collaboration that would help achieve this end.

Second, because findings suggest that maintaining the momentum of the conference may pose a challenge to participants, other platforms for collaboration might need to be considered. Interviewees suggested maintaining communication online and hosting regional conferences to address the barrier of geographic distance.

Plans To Extend the SENCER-ISE Initiative

With continued support from the National Science Foundation (*33*), the National Center is currently planning to continue the experiment on formulating HE and ISE partnerships by seeding several individual partnerships and creating an infrastructure to address the challenges identified by the evaluations of SENCER-ISE and from the literature on nonprofit partnerships. The current plans include:

- creating a joint organizing "secretariat," to provide communications and support through low-cost shared services for initially six civic engagement partnerships;
- providing modest "partnership support awards" and technical assistance to seed initially six HE-ISE civic engagement partnerships, and
- sharing evaluation and analysis services across all the partnerships.

The goal will be to enable movement beyond one-time, asymmetric partnerships bridging science education silos, to the creation of self-sustainable, balanced, and mutually beneficial relationships among HE and ISE institutions. The project will evaluate and report to the field the relative costs and benefits of each of the proposed mechanisms to nurture and maintain these partnerships. The project will provide faculty members in HE with tools from the ISE world to help improve undergraduate education. It will provide ISE institutions with ongoing refreshment and contact with scientists, teaching faculty, and students in the HE community, including their extensive civic engagement course experiences, many of which involve issues of sustainable practices and policies like studying energy usage and investigating effects of climate change. This will in turn assist ISE institutions in sharing current research by providing civic engagement opportunities for their diverse public audiences.

Beginning with the conversations at the March 2011 SENCER-ISE conference, it has been the hope of the investigators that we can develop a series of roadmaps to provide guidance for future collaborations between the higher education and informal science education communities. We hope to define the common essential goals and needs of successful partnerships and also highlight the individual efforts that speak to the needs of the specific locality or audience for which the partnership was developed.

References

1. NSF Grant Number DRL1001795.
2. SENCER. http://www.sencer.net/About/aboutus.cfm (accessed May 8, 2012).
3. CAISE. *Making Science Matter: Collaborations Between Informal Science Organizations and Schools*, 12. www.caise.insci.org (accessed April 13, 2012).
4. Kansas Enrichment Network. *Informal Science Education Strategy Session*, December 2009. http://www.kansasenrichment.net/assets/files/ISE%20Report_Final_6-17-10.pdf (accessed April 13, 2012).
5. Krathwohl, D. R.; Bloom, B. S.; Masia, B. B. *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain*. David McKay Co., Inc.: New York, 1973.
6. Bell, P., Lewenstein, B., Shouse, A. W., Feder, M. A., Eds.; *Learning Science in Informal Environments: People, Places, and Pursuits*; National Research Council, National Academies Press: Washington, DC, 2009.
7. Duschl, R. A., Schweingruber, H. A., Shouse, A. W., Eds.; *Taking Science to School: Learning and Teaching Science in Grades K-8*; National Research Council, National Academies Press: Washington, DC, 2007.
8. SENCER. http://serc.carleton.edu/sencer/newsletters/61795.html (accessed May 8, 2012).
9. For a background discussion on the conference and preliminary results, see Friedman, A. J.; Mappen, E. F. Establishing Connections between Formal and Informal Science Educators to Advance STEM Learning through Civic Engagement. *SECEIJ* **2011**, Summer, *3*, 2.
10. NCSCE. Executive Summary. *Science Education for New Civic Engagements Responsibilities, Informal Science Education (SENCER-ISE) Conference*. http://www.ncsce.net/Initiatives/SISEsumFinal.pdf.
11. NCSCE. *Science Education for New Civic Engagements and Responsibilities, Informal Science Education Conference Proceedings*; pp 8-17. Full conference proceedings are available at http://www.ncsce.net/Initiatives/documents/SISEFinal.pdf.
12. Proceedings, iii.
13. Executive Summary.
14. Friedman and Mappen.
15. Falk, J. H., Randol, S., Dierking, L. D. *Year I CAISE Landscape Study. A Preliminary Investigation*. http://caise.insci.org/uploads/docs/2008_CAISE_Landscape_Study_Report.pdf (accessed May 22, 2012).
16. For the six "Strands of Learning", see Bell et al.; pp 43−47.
17. For the SENCER Ideals, see SENCER.http://www.sencer.net/About/sencerideals.cfm (accessed May 22, 2012).
18. Friedman and Mappen, p 33.
19. Pacific Science Center. Portal to the Public. http://www.pacificsciencecenter.org/Portal-to-the-Public/portal-initiative.html (accessed May 24, 2012).

20. ASTC – Communicating Climate Change. http://www.astc.org/iglo/c3/ (accessed May 24, 2012).
21. Portal to the Public.
22. Ballou, J. Reshaping How Educators View Student STEM Learning: Assessment of the SENCER Experience. *SECEIJ* **2012**, Winter, *4*, 1.
23. Gupta, P.; Siegel, E. *Exemplary Science in Informal Settings*; NSTA Press: Arlington, VA, 2001; pp 71−83.
24. Alpert, C. L. *Small Steps, Big Impact*; Antill, J., illustrator, 2010. http://risepartnerguide.org (accessed May 24, 2012).
25. Dierking, L. D.; Falk, J. H.; Holland, D. G.; Fisher, S.; Schatz, D.; Wilke, L. *Collaboration: Critical Criteria for Success*; ASTC Washington, DC, 1997.
26. Hyman, V. *Lower Intensity Alliances (Part 1): When Less is More*; Fieldstone Alliance: Nashville, TN, 2005. http://www.fieldstonealliance.org/client/tools_you_can_use/08-23-05_Alliances.cfm (accessed May 24, 2012).
27. Kihl, K. L. Building Partnerships: The Good, the Bad, and the Ugly. *Informal Learning Review*, #100, January−February 2010; pp 1−5.
28. La Piana, D. *Nonprofit Mergers Workbook Part 1: The Leader's Guide to Considering, Negotiating, and Executing a Merger*; Fieldstone Alliance: Nashville, TN, n.d. http://www.fieldstonealliance.org/productdetails.cfm?PC=154 (accessed May 24, 2012).
29. La Piana, D. Merging Wisely. *Stanford Social Innovation Review*, #8, Spring 2010. http://www.ssireview.org/articles/entry/merging_wisely/ (accessed May 24, 2012).
30. New York Hall of Science. *The Science Career Ladder: 1986–2010*, 2011. http://www.nysci.org/media/file/SCL_Report_1986-2010.pdf (accessed May 24, 2012).
31. Schatz, D. and Russell, L. *Portal to the Public, First Synthesis Meeting Report*, 2008. http://www.pacificsciencecenter.org/images/stories/pdf/pop-synthesis-1-synopsis.pdf (accessed May 24, 2012).
32. Randi Korn & Associates. *SENCER-ISE Conference: An Evaluation*. http://www.ncsce.net/Initiatives/2011_RKA_NCSCE_SENCER-ISE%20eval_final.pdf (August 2011).
33. NSF Grant Number DRL1237463.

Chapter 10

SENCER and the Dual Poster Concept: Translating Science into Common Language

Le Shepard, Nicole Wallis, and Cynthia Maguire*

Department of Chemistry and Biochemistry, Texas Woman's University, P.O. Box 425859, Denton, Texas 76204
***E-mail: CMaguire@twu.edu**

Dual posters may be an effective way for science students to learn how to effectively communicate their research to non-science audiences. Many students do not understand the process of removing jargon and translating their work for the general public. The authors have created a handbook with a step-by-step process for translating existing scientific technical posters into a public poster version that is more easily understood by general audiences. Using this as a guide, student researchers learned how to explain their science in an understandable way while keeping the integrity of their science intact. Results of our pilot study of dual poster effectiveness are explained herein along with questions that focus our future research using this exciting new model.

Introduction

Texas Woman's University (TWU) is a public university with campuses located in Dallas, Denton, and Houston, Texas. Founded in 1901 as the Girls Industrial College, TWU today is the largest university primarily for women in the United States with a total enrollment of just over 14,700. About ten percent of TWU students are male; and it is listed as one of the top 10 most diverse universities in the nation with about 45% of students being members of a minority. (*U.S. News and World Report* 2012 Best Colleges) TWU has a large health sciences program, and is among the nation's leading providers of nurses and other healthcare professionals.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Early in 2010 the National Center for Science and Civic Engagement (NCSCE) selected TWU as the SENCER (**S**cience **E**ducation for **N**ew **C**ivic **E**ngagements and **R**esponsibilities) Center for Innovation–Southwest, one of one of six regional centers throughout the United States at that time. SENCER is a comprehensive faculty development and science education reform project funded by the National Science Foundation. With this honor, an added focus was placed on making science relevant.

Challenges to Communication

Many scientists do important work that could have a profound impact on their own field as well as others, but then struggle when communicating their results. Part of the challenge is that each discipline, and specialty within it, has jargon that is often not understood by the general public or others in complementary fields of research. By learning to reduce jargon and describe highly complex scientific studies in a manner most well-educated people can understand researchers in multiple disciplines will be better equipped to share the significance of their work with other researchers, more able to address problems together and better able to inform policy makers about their science.

At the 2010 SENCER Washington D.C. Symposium, Dr. Garon Smith (University of Montana, Missoula) and David Burns (National Center for Science and Civic Engagement) introduced the dual poster concept to the SENCER community as a way of addressing science communication difficulties. Over 1700 students who presented a typical scientific poster at the 24th National Conference on Undergraduate Research (NCUR) held April 15-17, 2010 were invited to create a second —public version. Only a handful of students agreed to do so. These paired posters were then presented side-by-side in order to show their scientific value within their own discipline, and communicate the relevance of their work to a general audience. While the concept was an innovative way of teaching science majors to communicate with the non-science public, there was considerable inconsistency in the results these students achieved. The technical posters were often unintelligible to the average person and although it was obvious that the students had worked hard, the public version posters were not always understandable either. A way of achieving a more consistent result was needed.

Related Research

Questions that may be answered by studying learning in the context of preparing dual posters are generally in the nature of those found in the scholarship of teaching and learning (SoTL) literature. Randy Bass (*1*) offered perhaps the most famous description of SoTL questions when he wrote the following:

> One telling measure of how differently teaching is regarded from traditional scholarship or research within the academy is what a difference it makes to have a problem in one versus the other…. Asking a colleague about a *problem* in his or her research is an invitation;

asking about a problem in one's teaching would probably seem like an accusation. Changing the status of the *problem* in teaching from terminal remediation to ongoing investigation is precisely what the movement for a scholarship of teaching is all about. (p. 1)

Pat Hutchings (*2*) described the taxonomy of SoTL questions, including what is, what works, what can be and developing new frameworks. The dual poster project will eventually involve questions in most of these categories. Kathleen McKinney (*3*) provides an excellent and fairly concise reference for those less than familiar with this area of scholarship who might wish to pursue their own teaching and learning questions. For those who prefer to learn online, the International Society for the Scholarship of Teaching and Learning website has a thorough SoTL tutorial available (*4*). This organization also sponsors an annual institute where researchers are mentored to improve their work involving SoTL questions.

There is a relation between the kind of question asked and research design. Questions that ask how or why are best answered using qualitative methods, while questions that address differences between groups may be measured most effectively by quantitative methods (*5*). McKinney (*3*) simplifies it this way: quantitative data are in numerical form and may involve large quantities of data while qualitative data tend to be limited and verbal.

Most research involving natural sciences is quantitative, so it is worth noting that qualitative research has also been used successfully. Otero and Harlow (*6*) describe strategies and procedures for collecting and analyzing qualitative data and discuss other aspects of qualitative research as it applies to physics education research. Essentially, through proper analysis and coding, qualitative data can give valid and consistent results. Since qualitative data collection allows measurements with a small—sometimes extremely small—sample size, it is particularly suited to use in this research. As we began use of a new tool in creating public posters from technical work, only three students were recruited. Two succeeded in completing public versions of their work.

We are early in the process of learning how we learn a discipline, and how learning in one discipline varies from learning in another. Even intelligent and well-trained experts in one field may struggle if confronted with undergraduate coursework in a different academic specialty. There is ample room for research on how people think and how students learn within a discipline. The challenge for academics is how to improve student success in their classrooms and laboratories. Mental skills needed for undergraduate success vary widely among disciplines and these thought processes are not generally explicitly taught. In fact, many faculty gravitated toward a field in which they already possessed the required thinking processes without even realizing how they learn. This makes it difficult to teach the thought processes required for success. Middendorf and Pace (*7*) did an excellent job of describing this situation in *Decoding the Disciplines: Helping Students Learn Disciplinary Ways of Thinking*. They offer a series of steps that provide a framework to discover ways of thinking and learning. Further, these steps reveal to students that difficult information becomes manageable when broken down into its parts. Their work contributes significantly to understanding the dual poster concept goal of learning to communicate across and among disciplines.

Finally, as educators we tend to focus on measuring visible learning as demonstrated by a finished product—assessing an exam, paper, presentation, etc. Frequently, however, what our students learn is invisible to our measurements. In recent years, the SoTL community has focused on this, referring to it as "making the invisible visible" (*8*). Bass and Eynon discuss this idea in some detail, particularly the use of qualitative methods to reveal the stepwise progression from novice to expert. The dual poster project is focused on revealing the invisible intermediates inside our students' minds, making them visible. By guiding students through the steps essential to acquiring the needed communication skills, we can guide our students from novices to professional scientists.

TWU Pilot Study

Shepard, Wallis and Maguire were part of the TWU team attending the SENCER meeting where Smith and Burns presented the dual poster concept and invited the audience to take the idea and develop it wherever an interest was present. Back home in Texas, they decided to do a trial study during the 2010 - 2011 school year to see if they could obtain more consistent results among TWU science students. At that time Shepard was a senior majoring in psychology. Wallis was a senior majoring in elementary education. Both students had completed their core science requirements prior to beginning this project. Maguire is a senior lecturer in chemistry, teaching mostly core science courses, but is not doing active bench research. Together they felt they would be an ideal team to act as a sounding board to guide science student researchers toward completion of a public version of their original technical work.

To organize the process, Shepard and Wallis wrote a handbook to be a step-by-step guide for translating existing scientific posters into a public poster version. The handbook breaks down the process of creating a public version poster into separate exercises in which the original technical writing is rewritten with jargon removed and explained in common vocabulary. The exercises focus on the title, abstract, body and conclusion of the poster; and a critical review. In each one, emphasis is placed on communicating the value of the knowledge gained from the research.

At the same time, Maguire approached science faculty to ask their support in enlisting students enrolled in research to participate in the pilot study. Three students were identified: one undergraduate and two graduate. Two were enrolled in Chemistry programs, one in Biology. Each student had a different faculty mentor.

Students then worked through the handbook provided with Shepard as a mentor, and working alone some of the time, to create their public version posters. Because the use of jargon is so rampant within disciplines, it can be very difficult for students to explain their studies in the common vernacular. Each of our participants struggled with using common language in their work because either the concepts were especially complex or they preferred the more scientific sound of their technical wording. By working through many small steps, the

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

students learned how to keep the integrity of their science intact *and* explain it to a broader audience in an understandable way. When they felt it was done, Maguire reviewed each student's public poster and offered additional comments for their consideration. The final reviewers were the faculty mentors for each student participant.

A brief description of the two poster topics might be helpful to our readers. The chemistry researchers measured how the conformation of DNA telomeres, found at the ends of all chromosomes, changes under varying conditions. Telomeres have unique structures associated with the onset of cancer and aging. This research may potentially lead to more effective anti-cancer drugs (*9*). The biology project sought to examine adaptations of both the honeybee and sunflowers as they have evolved together in a mutualistic relationship (*10*). As an example of the transformation between technical and public posters, we show the titles of each project in Figure 1.

Chemistry Posters (*9*)

Technical Title: A Spectroscopic and Calorimetric Investigation of the Human Telomere DNA Sequence

Public Title: Unusual DNA Structures and their Potential Role in New Cancer Therapies

Biology Posters (10)

Technical Title: Microscopic Studies of the Mutualistic Relationship between the Sunflower and the Honey Bee

Public Title: Understanding the Relationship between Honeybees and Sunflowers

Figure 1. Dual Poster Titles.

To measure effectiveness of communication, each pair of posters (technical and public versions) were shown to students in an undergraduate core science class to gauge their understanding of each version. A short survey (see Figure 2) was administered during class; a total of 63 surveys were collected. Respondents first examined the technical version of a poster, and responded to four statements. Next, the public version was shown along with the same four statements. Of those who responded 12 (19%) were lower division and 51 (81%) were juniors or seniors. Only eight (13%) were science majors. There were 58 (92%) women and 5 (8%) men. The mean age of respondents was 24.98 years old.

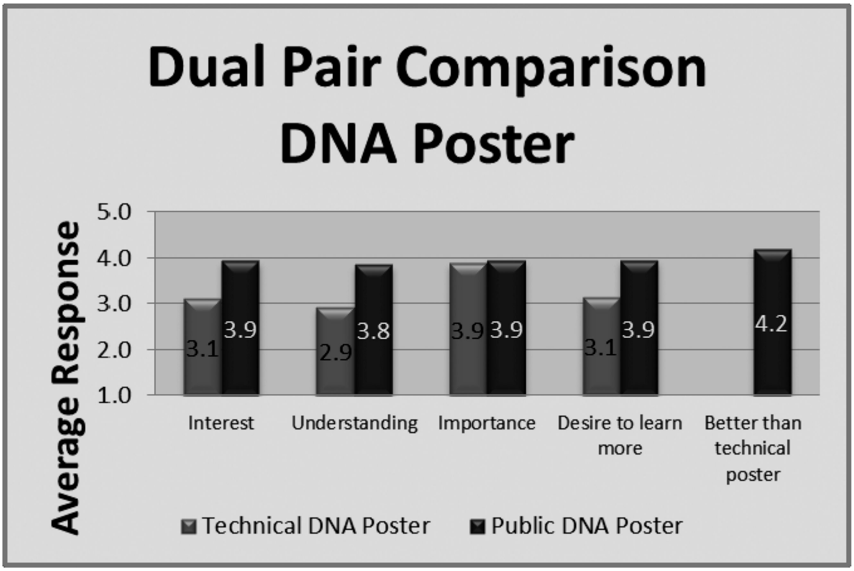
Rate how much you agree with the following statements using a five-point scale from (5) Strongly agree to (1) Strongly disagree.

a) I am interested in this poster.
b) I understand what this poster is about.
c) I think this research is important.
d) I want to learn more about this topic.
e) A fifth statement added after viewing the public poster asked viewers to rate agreement with whether they thought the public version was “better than the technical poster?”

Figure 2. Survey Statements.

Figure 3 displays the results of the pilot survey. For each measure studied, the public poster outperformed the technical. Interest, understanding, perceived importance of the research, and desire to learn more increased in agreement among viewers for the public version, with only one exception for each pair. Perceived importance of the DNA research and desire to learn more about the sunflower and honeybee rated a tie among viewers. Perhaps more importantly, the DNA public poster was rated 4.2, between Somewhat agree (4) and Strongly agree (5), when viewers were asked whether it was better than the technical poster, indicating a strong preference for the version with less jargon. In contrast, the sunflower and honeybee study was rated 3.3 for the same measure. This indicates agreement, but only slightly more than neutral (3). From this data, we conclude that the more detailed the technical poster, the greater the improvement in understanding for the public version. Although this warrants further study, it is encouraging news for those in highly specialized technical disciplines.

Last, open-ended comments were solicited. One fairly typical respondent wrote that the technical poster was “boring [and] hard to understand”, while the public version was “...really important because I lost my grandma to cancer. We should study this more.”



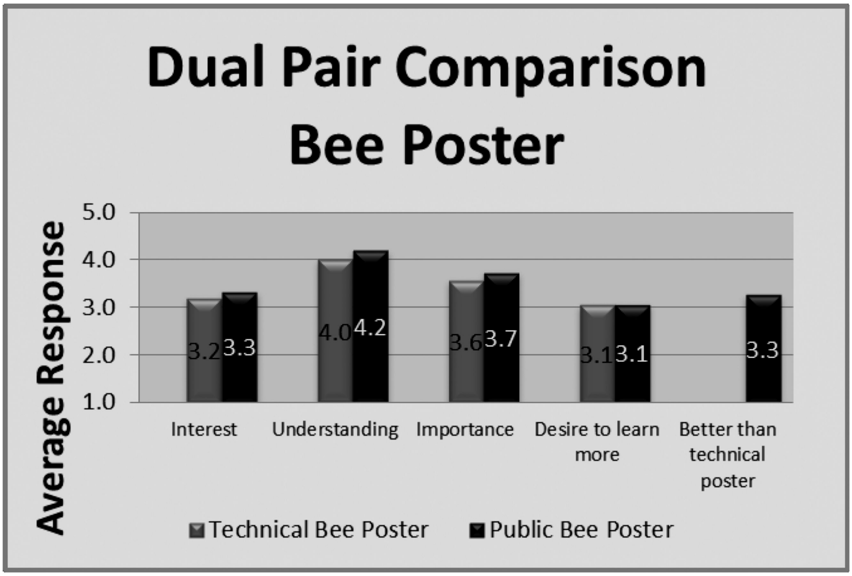


Figure 3. Survey results evaluating dual posters. Responses were (5) Strongly agree, (4) Somewhat agree, (3) Neutral, (2) Somewhat disagree and (1) Strongly disagree.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Future Possibilities

The authors discovered that faculty mentors and student researchers vary considerably in their enthusiasm for the process of developing public versions of technical posters. Of the three students in our pilot project, one did not understand the significance of her research and has not completed her public poster as of this report. She has since changed mentors and expressed a desire to work with us on a future research project. Faculty mentors anticipated this possibility and felt that the dual poster project would provide a good checkpoint, enabling them to measure comprehension of science topics within their own research groups, and improve outcomes where needed.

Once created, dual posters can be used as recruitment tools. For example, displaying a pair side-by-side during an open house can inform prospective students (and their families), who do not yet have an advanced understanding of the discipline. Dual pairs can be used as the starting point for multidisciplinary collaborative work. They can also be tools for teaching non-scientists about complex ideas in a more understandable way.

Important questions to pursue in future research are,

1. What effect does preparing a public poster have on the student researcher?
2. How do students learn to translate scientific findings for a general audience?
3. Does translating technical scientific findings for a general audience lead to deeper scientific understanding on the part of students? and
4. What is the impact on participating faculty mentors?

Each of these questions is addressable using generally accepted concepts and methods in the SoTL research community. The authors plan to proceed by coding qualitative data in written journals kept during development of dual posters and during oral interviews with student researchers and their mentors.

This pilot was the first empirical analysis of the effectiveness of dual posters. While it showed great promise, there is obviously more work to be done. Beginning in the 2012-13 school year, a follow-up study is planned. Collaborators are sought to work on this concept in a variety of academic institutions and disciplines. We now have some basis to say that creating a public version of a technical research poster may be an effective tool, but considering our extremely small sample size additional data from other institutions is desirable to add credibility to this claim. We also want to encourage adoption of this idea at other institutions in order to examine how broadly it may appeal in a variety of circumstances.

References

1. Bass, R. The Scholarship of Teaching: What's the Problem? *Inventio: Creative Thinking about Learning and Teaching* **1999**, *1* (1), 1–10.
2. Hutchings, P. *Opening Lines: Approaches to the Scholarship of Teaching and Learning*; The Carnegie Foundation for the Advancement of Teaching: Menlo Park, CA, 2000.
3. McKinney, K. *Enhancing Learning through the Scholarship of Teaching and Learning: The Challenges and Joys of Juggling*; Jossey- Bass/Anker: San Francisco, 2007.
4. International Society for the Scholarship of Teaching and Learning web tutorial. http://www.issotl.org/tutorial/sotltutorial/home.html.
5. Bunce, D. M., Cole. R. S., Eds.; *Nuts and Bolts of Chemical Education Research*; Oxford University Press: New York, 2007.
6. Otero, V. K.; Harlow, D. B. Getting Started in Qualitative Physics Education Research. In *Getting Started in PER*; Henderson, C., Harper, K. A., Eds.; American Association of Physics Teachers: College Park, MD, 2009.
7. Middendorf, J., Pace, D., Eds.; *Decoding the Disciplines: Helping Students Learn Disciplinary Ways of Thinking*; New Directions for Teaching and Learning, No. 98, Summer 2004; Jossey-Bass: San Francisco, 2004.
8. Bass, R.; Eynon, B. *Academic Commons*, 2009. http://academic commons.org/commons/essay/capturing-visible-evidence-invisible-learning (accessed May 2012).
9. Tucker, B.; Gabriel, S.; Antonacci, C.; Sheardy, R. D. *A Spectroscopic and Calorimetric Investigation of the Human Telomere DNA Sequence* and *Unusual DNA Structures and their Potential Role in New Cancer Therapies*; Texas Woman's University, Department of Chemistry and Biochemistry: Denton, TX, 2010; unpublished.
10. Wojtaszek, J.; Maier, C. *Microscopic Studies of the Mutualistic Relationship between the Sunflower and the Honey Bee* and *Understanding the Relationship between Honeybees and Sunflowers*; Texas Woman's University, Department of Biology: Denton, TX, 2010; unpublished.

Chapter 11

Disseminating Curricular Models: Bringing SENCER to the Next Level

Eliza Jane Reilly*

Director, The Phillips Museum of Art, Franklin & Marshall College
General Editor, SENCER Model Series
***E-mail: Eliza.reilly@fandm.edu**

This essay is a summary of where we have been, and where we hope to go, in the dissemination of the curricular innovations and reforms that faculties and their institutions have produced under the banner of the SENCER project. It provides a review of the original dissemination strategy formulated during the first iteration of the project, and traces some encouraging, and unanticipated, developments in the ways that individual faculty, departments, programs, and entire institutions have used SENCER strategies to leverage larger-scale curricular change--beyond the course, and beyond undergraduate STEM education for non-majors in the second phase. It will conclude with a proposed strategy for a third phase of dissemination that has two goals: transforming heuristic models into accessible and easily adopted materials, and creating web-based strategy for representing the multi-course, institution-wide, and multi-institutional initiatives catalyzed by SENCER participants.

The SENCER Models-Phase I

By definition SENCER model courses are field-tested curricular approaches that improve science learning while supporting direct student engagement with complex civic issues. They teach rigorous STEM content through the "lens" of a problem of public consequence. The course was chosen as the unit of dissemination for two important reasons: 1) the course is the basic unit of instruction in undergraduate education across the spectrum of institutional types,

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

and 2) course design is the area of curriculum development where individual faculty members have the most discretion and creative input. It is important to note that SENCER models were intended as heuristic and exemplary, and not prescriptive—they were intended as a spur to, and showcase for, innovative approaches that could be adapted in all disciplines and at a wide variety of colleges and universities. Additional criteria for selecting courses as SENCER models were that strong assessment strategies were embedded in the design, and that they invite students to put their scientific knowledge and the scientific method to immediate use in addressing complex civic problems (*1*).

Selected models are published electronically on the SENCER website (www.sencer.net) where they are among the most-often accessed resources. Originally published as downloadable PDF files, the models were converted to HTML in 2009, given metadata tags, and incorporated into a searchable "SENCER Digital Library" of electronic resources that was launched in 2010. To date there are 45 SENCER models available in this new format and that number will continue to grow.

SENCER Models Phase II: The Expansion of the "Model" Concept Beyond the Course

In the second phase of SENCER it became clear that adopters were moving the concept beyond the boundary of the individual course to integrated curricular programs, and even beyond general education to upper-division courses, majors and graduate studies. Using the SENCER models as indicators, it is possible to identify some encouraging, and unanticipated, developments in the ways that individual faculty, departments, programs, and entire institutions have used SENCER strategies to advance both STEM education and civic engagement. The range of innovation is impressive and diverse, including linked courses, course intersections and modules, topical intersections, and inter-institutional partnerships.

In considering the potential for large-scale STEM education reform, three trends, in particular, are worth highlighting.

The "SENCERIZATION" of General Education Programs

Several models have emerged from more systematic reforms of general education programs that used civic questions as organizing frameworks. One of the first model submissions that represented an entire curricular program, rather than a single course, was a 2008 selection "Food for Thought: Engaging the Citizen in the Science and Politics of Food Information, Food Consumerism, Nutrition and Health," an Integrative Liberal Studies Topical Cluster at the University of North Carolina at Asheville that uses the SENCER strategy to reorganize and extend general education to the entire undergraduate experience, while using civic questions to forge links among and between disciplines (*2*).

In this model undergraduates take their general education distribution in natural science, social science, and humanities in topical clusters centered on a

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

common civic question. The *Food for Thought* cluster focuses on the intersection of science and policy by exploring the role of food in chemical, biological, and social systems. Its goal is to help the student become an informed consumer of food by providing a platform for discussion of what we eat, why we eat, where our food comes from and how it is processed, and how food affects our bodies and health.

Students enrolled in various *Food for Thought* cluster courses throughout their undergraduate career. Each course has specific learning goals related to both the individual discipline and the mission of the cluster. Courses in this cluster drew from Chemistry, Biology, Nutrition, Economics and Sociology and include HWP 373 Food Politics and Nutrition Policy, CHEM 174 Live Learn and Eat: the Food of Chemistry, and ECON 245 Land Economics: Connecting Land and People. Students in any single course will contribute class content to students in another course, a strategy that enables students to gain an appreciation of specialized knowledge, while also recognizing the limits of any single discipline for solving complex problems. This model also exemplified the SENCER goal of matching pedagogy to content and drew on a range of pedagogies, both traditional and innovative, including lectures and literature reviews, group projects, field trips, peer-led learning, poster presentations, laboratory experiments, and independent research.

SENCER for STEM Majors and Graduate Students

In the early days of the SENCER initiatives, participants were enthusiastic about the potential of its concept and strategy to reach non-majors and science-averse students, but often insisted that the approach would never work in the major, where the pressure to convey specific disciplinary knowledge discouraged the introduction of non-STEM themes or content. By 2008, however, SENCER model submissions reflected an increase in interdisciplinary courses explicitly aimed at upper division students, such as Franklin & Marshall's "Pregnancy Outcomes in American Women," a team-taught capstone course that brought together advanced students from various disciplines in the sciences and social sciences to explore a pressing social and public health problem (*3*).

The following year, two courses for STEM majors were featured, both of them designed by participating SENCER faculty. Dr. Matt Fisher, Associate Professor of Chemistry at St. Vincent College submitted model specifically developed as a SENCER course for majors: "Undergraduate Biochemistry Through Public Health Issues." This two-semester sequence for science majors was designed to both convey canonical biochemistry content needed for the major, and link that content to broader contexts that would prepare students for advanced work graduate or professional programs in public health.

Kelly Wentz Hunter, Assistant Professor, Biology, Roosevelt University submitted "Cellular and Molecular Biology: Cancer," a core curriculum course for biology majors that serves as the foundation for the upper-level majors' courses. Previously this course had been taught as a traditional, content-driven biology course, but was redesigned to connect the concepts of cellular and

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

molecular biology to complex diseases using the uniting theme of cancer. The course included a cancer centered, civic engagement project component.

This year, 2012, the featured model provided an outstanding example of how exploring science content through civic questions is a strategy that can improve advanced education in the STEM disciplines and professions, while impacting public understanding of science.

"Science outreach - Public Understanding of Science," developed by Hannah Alexander, Adjunct Associate Professor, Division of Biological Sciences, University of Missouri, Columbia, is an interactive course that aims to train future scientists and science educators from a range of disciplines and professions to communicate science to the public in an understandable and inviting fashion. Students who take the course come from various different academic departments, including Biology, Immunology, Geology, Neuroscience, Fisheries and Wildlife, and Animal Science, have widely different scientific backgrounds, They are free to choose their presentation topics and encouraged to base them on issues of strong personal interest, as long as they are not directly part of their graduate thesis research University faculty members, experts in the latest scientific research in the related fields, are asked to mentor the students, both for accuracy of the presentation as well as for guidance in preparing and delivering the presentations. In the past several years, students generated 35 different presentations, and have given over 110 presentations to adult audiences in the community.

Inter-Institutional Collaborations

A third trend that has expanded the reach of SENCER strategies beyond the individual course is toward inter-institutional collaborations. This trend has appeared in a number of models, with one of the earliest being the 2008's "Life Science in Context: Sub-Saharan Africa and HIV/AIDS," developed by John A. Mecham, Department of Biological Sciences, Meredith College, Erica Kosal, Department of Biology, North Carolina Wesleyan College, and Dr. Pearl Fernades, Department of Biology, University of South Carolina Sumter. This successful inter-institutional collaboration capitalized on regional networks and expertise to integrate HIV/AIDS into different courses, two of them designed for majors, at three undergraduate institutions. At Meredith College "Life Science in Context: Sub-Saharan Africa" is an Honors Colloquium in bioscience that focuses on HIV/AIDS and nutrition. At North Carolina Wesleyan, "East African Wildlife and Human Interactions" is a biology course that explores interactions between wildlife and humans, including the question of how HIV crossed over from chimpanzees to humans. At the University of South Carolina, Sumter, the biology course "Human Anatomy and Physiology" is a lecture and lab course taken by all Biology and Nursing majors and covers the biology, statistics, testing, and transmission of HIV/AIDS. To ensure that the science of HIV/AIDS was learned in a larger civic and social context of the sub-Sahara, consortium members worked with local and international experts, including faculty from collaborating peers from Duke University and two Kenyan national universities, Kenyatta University and Edgerton University.

This linking of a group of US campuses with African universities around the global AIDS crisis was integrally connected to another SENCER model of institutional collaboration that suggests the potential for SENCER strategies to "scale up" its impact on both STEM education and public health. "AIDS Research: Global Understanding and Engagement (ARGUE)" was developed in 2000 by Sherryl Broverman, Associate Professor of the Practice, Department of Biology, at Duke University. This introductory science course for non-majors and pre-majors directly links curricula at Duke University and Egerton University, a women's college in Kenya, by teaching the science related to HIV/AIDS through collaborative learning and common research projects. The research projects are determined every year by the teaching and community-outreach needs of Egerton staff and students, and more recently by a partner school and community near Lake Victoria. The products of this undergraduate research have included curricula on HIV/AIDS (which has been used by over 2000 students at Egerton), HIV peer education materials, resources on the relationship between gender inequality and health, and programs to support girls' education.

Organizing Phase III of SENCER Model Dissemination

The models emerging from Phase II of SENCER represent just a sampling of the diversity and scope of innovation catalyzed by SENCER faculty and their institutions. The dissemination strategy for the models has evolved beyond discrete hard-copy or electronic texts (PDF) to a tagged and searchable HTML format that is integrated into the National Science Digital Library. Faculty who have developed courses or programs that they believe exemplify the SENCER ideals can now upload their materials directly to the SENCER model site through a user-friendly content management system. Models must still be peer reviewed before inclusion in the series, but the new format has essentially eliminated most of the material barriers to an exponential expansion of the model series.

Plans for Phase III of model dissemination have been informed by an analysis of the trends emerging from the SENCER project, as well as the acknowledgement that the pace of change, both in curricular innovation and technological delivery systems, has been more rapid than anticipated a decade ago. More investigation and research may be needed to identify the optimum approach to dissemination, but the following goals have been identified.

Goal I: From Models to Materials

Because the course continues to be both the basic unit of curricular organization and of faculty creativity SENCER will continue to expand the pool of "models," which continue to embody SENCER ideals in action, and represent the curricular creativity and improvement. But the very multiplicity of curricular formats and platforms also adds complexity to the question of how to most effectively "package" the very diverse content embedded SENCER models for adoption and widespread use, particularly in institutional contexts where the bar for creating entirely new courses and programs is discouragingly high.

Proposed Organizing Strategy: Collections

To this end we have proposed the creation of Task Force to analyze and organize Models into "collections" and formats suited for use in different contexts. This will require an in-depth consideration of both the needs of potential audiences for the material, and the appropriate delivery systems for reaching that audience. Collections would be launched each year and be grouped according to different constituent interests and needs. Examples of organizing platforms for collections would be discipline (Biology, Chemistry, Mathematics, etc), pedagogies (service learning, learning communities, laboratory and field research, etc). Examples of formats could range from modules (to be inserted into traditional courses) and case studies, to whole courses and course sequences. Dissemination would continue to be through searchable online-access. A significant charge for the task force will be proposing a design for the continuous development and sustainability of SENCER Collections. Formative feedback will be solicited and used to continuously shape and improve the production and presentation of materials, as well as to determine commercial potential of the content and format.

Goal II: Bringing SENCER to Scale

While collections serve as a strategy for packaging SENCER content and pedagogy in smaller and more easily adopted units for use in courses, there remains the challenge of representing and disseminating larger-scale SENCER reforms that have been documented in the models, in team application and presentations at the SENCER Summer Institute, and poster sessions at the Washington, DC symposia. All three provide clear indications that institutions have been using SENCER strategies to catalyze larger-scale curricular reforms, not only of general education curricula, but of majors and interdisciplinary programs, and graduate education. In addition SENCER has been the springboard for inter-institutional collaborations and consortia, and co-curricular programs. The diversity of these initiatives makes them difficult to capture, represent, and disseminate, but their number and impact are significant and growing and could be of great value to academic leaders responsible for managing and advancing change in their institutions.

Organizing Strategy: National Symposium

To call attention to these developments, and to begin the process of analyzing their potential impact, we have proposed the following timeline of events.

- Year 1: Organization of a national symposium
- Year 2: Use proceedings and additional essays to create a book of case studies describing "models" of large-scale SENCER applications
- Year 3: Create web-based strategy for representing and disseminating multi-course, institution-wide, and multi-institutional initiatives.

As the SENCER model series enters its 13th year we can expect that it will continue to document and reflect the energy, imagination, creativity, and ambition of dedicated educators who continue to inspire their students by teaching "through" complex, capacious, civic questions that affect us all. Their leadership, at all levels, will continue to lead higher education in exciting new directions. Our goals for Phase III of the models is to convey their remarkable innovations and achievements to the widest audience possible.

References

1. For a more complete history of the origin and evolution of the SENCER models, see Reilly, E. J. The SENCER Models. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 25−34.
2. UNCA faculty developers for this model are Sally A. Wasileski, Department of Chemistry; David Clarke, Department of Biology; Karin E. Peterson, Department of Sociology; Amy Joy Lanou, Department of Health and Wellness; and Leah G. Mathews, Department of Economics.
3. Crable, A.Faculty Studies, Team-Teaches Course about Pregnancy Outcomes in American Women. *Franklin & Marshall Magazine*, Spring 2007, pp 10−11

Chapter 12

STEM Practice and Assessment: SENCER's Influence on Educators

Danielle Kraus Tarka* and Janice Ballou*

SENCER, 1606 New Hampshire Avenue N.W., Washington, DC 20009
***E-mails: danielle.kraus@sencer.net; jballou@optonline.net**

Science Education for New Civic Engagements and Responsibilities (SENCER) was envisioned to improve undergraduate STEM (science, technology, engineering and mathematics) education by making student learning real, relevant, rigorous, and responsible. To achieve these objectives, the SENCER approach employs several methods to encourage change in how faculty and institutions practice student learning. SENCER recognizes that change in practice goes hand in hand with assessment. Instructors and institutions who adapt their STEM instruction to the SENCER approach based on research about student learning and best practices need to have the tools and training to conduct formative assessments to find out how their students are doing.

This chapter summarizes the context and research that is the foundation of the SENCER approach. An overview of SENCER methods used to encourage change describes the experiences of program participants that are expected to result in improved undergraduate STEM learning. To find out if these changes make a difference, we review the various types of assessments used to measure the attainment of SENCER objectives.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Literature Review

Overview of STEM Objectives for Pedagogical Practice

SENCER promotes the connection of STEM content to complex local, national, and global challenges to improve education. As a faculty empowerment program, SENCER promotes scholarship and the incorporation of best practices from research into the science of learning into teaching methods. Most notably, SENCER promotes best practices highlighted by the science of learning including connecting course content to real world problems – contextualizing the learning for the student, the use of clear learning goals in course design, and the use of frequent, formative assessments to gauge how students are learning and adjust teaching accordingly.

Faculty are increasingly identifying the effectiveness of contextualized teaching, using real-world problems students can relate to as a vehicle for STEM content. The Mathematical Association of America asserts that educated adults should be able to solve real problems with what they learn (*1*), and other groups have made similar statements regarding the importance of developing competency in applying knowledge to new and varying situations (*2*, *3*). Contextualized teaching is often also interdisciplinary, leading students to make connections across disciplines to recognize the full nature of a problem and the applications of knowledge to solving. Interdisciplinary collaborations can also be a significant means of professional development for faculty, and contribute to institutional change when these collaborations are applied to the larger general education or degree curricula (*4–6*). The *Bio 2010* report references interdisciplinary teaching as necessary to improve all education (*7*).

Examples from SENCER Programs

Many of the educators involved in the SENCER community of practice since 2001 have published results of their campus interventions that relate the effectiveness of teaching course topics in the context of civic challenges. For example, Kosal et al (*8*) cite a content-driven, interdisciplinary course on water that represented a partnership among biology, chemistry, and math faculty members. Students responded positively to the incorporation of real-world issues and assessments showed that the course approach led to improved student science literacy, comprehension of course content, and interest in STEM. Kosal was also part of a collaboration that established multi-institutional and international partnerships with faculty members and students in sub-Saharan Africa around HIV/AIDS; a program that was recognized as a SENCER model in 2008. Chekuri et al (*9*) found that by applying an interdisciplinary approach to teaching physics, mathematics, psychology, engineering, and architecture content through issues concerning traffic in Los Angeles, course assessments showed student gains in content knowledge and self-perceived gains in comfort levels of discussing these issues with others. Improved student learning and interest in math were also outcomes of the introduction of civic engagement in a pre-college algebra course (*10*). Pfaff et al (*11*) found introducing context aided student understanding of calculus concepts. Students in a course on community health at Merrimack

College considered a focus on real-world issues helpful to their learning, and ranked such activities highest on course evaluations (*12*).

Incorporating real-world applications into courses can be particularly valuable for students preparing to enter into education as a profession. As reports such as *Taking Science to School* note, science should be taught in a way that models how science is done; so courses for future teachers should model the best practices that they will later incorporate into their own teaching (*13*, *14*). Educators have found this approach effective for engaging future teachers and improving confidence in STEM. Kim et al (*15*) incorporated civic issues and service-learning into a chemistry course for elementary education majors, with results demonstrating that students recognized the importance of engaging their own students in hands-on activities to reinforce course content. Fink (*16*), another member of the SENCER community, found positive changes in students' attitudes and engagement with biology content after integrating civic issues into a course for future teachers.

This sample of campus work cited here illustrates some of the many positive outcomes in courses and programs that incorporate civic engagement as a method to improve student learning, interest, and confidence in STEM, as well as hint at the diversity of applications and issues represented in the SENCER community. Additional information on results of student gains in SENCER courses and programs can be found at www.sencer.net. Peer-reviewed articles can also be found in *Science and Civic Engagement: An International Journal,* which focuses on the use of unsolved civic issues as a framework for developing student knowledge and is a publication of the National Center for Science and Civic Engagement (NCSCE).

National Focus on STEM Assessment

Underscoring the value of assessment and the implementation challenge, particularly as it relates to STEM teaching practice and evaluation, is the 2003 National Research Council (NRC) report *Evaluation and improving undergraduate teaching in science, technology, engineering, and mathematics* (*17*). And while there are other sources addressing this issue, the 2003 NRC report is a useful roadmap to the issues and state of knowledge related to STEM teaching practice and evaluation. We use this document with its comprehensive outline and references as a national guideline for discussing STEM assessment. The NCR report provides an operational definition we can use to standardize what we mean by STEM undergraduate assessment:

> To many, the word "assessment" simply means the process by which we assign students grades. Assessment is much more than this, however. Assessment is a mechanism for providing instructors with data for improving their teaching methods and for guiding and motivating students to be actively involved in their own learning. As such, assessment provides important feedback to both instructors and students. (p.72)

While the value of assessment is recognized and encouraged, the 2003 NRC report notes it is in jeopardy because undergraduate faculty have competing demands on their time and they are skeptical about the conduct of assessments. Maybe more importantly, even when assessment is acknowledged as being beneficial to both the instructor and the student, it is not a tool faculty typically know how to integrate into their teaching practice:

> Yet the committee found that most faculty who teach undergraduates in the STEM disciplines have received little formal training in teaching techniques, in assessing student learning, or in evaluating teaching effectiveness. (P2)

As suggested in the NCR report, the *Assessment Forum: Nine Principles of Good Practice for Assessing Student Learning* (*18*) provides a useful set of guidelines to develop program assessment objectives and to compare to the SENCER approach. Table 1 summarizes the nine principles described by the authors.

Table 1. Principals for Assessing Student Learning

1. The assessment of student learning begins with educational values.
2. Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated, and revealed in performance over time.
3. Assessment works best when the programs it seeks to improve have clear, explicitly stated purposes.
4. Assessment requires attention to outcomes but also and equally to the experiences that lead to those outcomes.
5. Assessment works best when it is ongoing not episodic.
6. Assessment fosters wider improvement when representatives from across the educational community are involved.
7. Assessment makes a difference when it begins with issues of use and illuminates questions that people really care about.
8. Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change.
9. Through assessment, educators meet responsibilities to students and to the public.

Sources for information in table: refs (*17*, *18*).

Taking these principals and using them to get useful assessment information requires multiple sources. The NCR report advises using multiple sources to get a comprehensive assessment and provides an overview of the range of different types of evaluations (Table 2, (*17*)).

Table 2. Overview of Types of Evaluations

1. Evaluations by:
- Undergraduate students
- Graduating seniors and alumni
- Teaching assistants
- Faculty colleagues
2.Evaluation of course materials
3.Instructional contributions
4.Use of students for classroom observations
Self evaluation by faculty - Reports on teaching activities - Self report
Institutional data and records

There is a plethora of information that, over the years, has concluded assessment is needed to evaluate any educational approach. The literature on the practice of education provides various examples of the value. There are also multiple and on-going resources available on "how to" guidelines for assessments. Yet, there is general agreement that it can be challenging to actually make it happen.

Reasons for Assessment

Frequent and formative assessments are recommended by SENCER as necessary to effective course and program design, and should be integral to the teaching and learning process at all levels of education. Smith defines formative assessments as activities that "continually assess students' learning progress with feedback to students and instructors that determine the course of subsequent teaching and learning activities" (*19*). The key characteristic of these activities is that they inform the course instruction in progress, so as to improve learning outcomes for students. Once educators are aware of what students do not understand or where they are "lost," it becomes an imperative to respond to that information and adjust instruction accordingly to improve outcomes (*20*). Formative assessments oppose the sole use of summative assessments that show what students have missed only when there is no possibility of changing the outcome or improving the students' understanding of the course topics.

The authors of the seminal report How People Learn: Bridging Research and Practice consider formative assessments "essential" to a well-structured course (*21*). A classic, comprehensive review on methods of formative assessment and their use by Black and Wiliam found that formative assessment effectively raises learning gains, especially for low achievers (*22*). In a preface to the reprinting of the summary, they also note that these methods are not being used as widely as they should by educators at all levels, and recommend a professional development structure that would demonstrate the benefits on a local level of working formative assessments into their classrooms (*23*). These authors and others reiterate the importance of working formative assessments into more courses.

A study by Deslauries et al utilized control and experimental sections of a physics course to judge impact of utilizing best practices in cognitive science, such as formative assessments (*24*). The experiment section (taught by a graduate assistant who applied methods as recommended by cognitive science research) used formative assessments including clickers and quizzes whose results the instructor responded to immediately. Students in this section performed twice as well on the exam as the control section, which was taught by a dynamic and experienced professor. Smith also found a correlation between the use of formative assessments and student achievement on exams (*25*).

The use of clear learning goals and formative assessments that work to achieve these goals may also improve communication between educator and student. Straits and Wilke note the importance role assessment loops in the classroom play in student learning (*26*). Ludwig et al suggest noting assessment activities in the syllabus so that students are both aware of the structure of the course and understand the purpose of the assessments – that the instructor is focused on improving their understanding of the course concepts (*27*). Others suggest that course specific learning goals can provide a structure for developing formative assessment activities (*28*, *29*). By communicating transparently about the learning goals for the course, students understood more about the course structure and the instructors' aims. Instructors also benefited from this enhanced communication with students.

SENCER Methods To Encourage Change

Goals

SENCER encourages change in participant pedagogical practices to achieve the goals of improving student learning and making STEM education real, relevant, rigorous, and responsible. The approaches SENCER encourages educators to adapt in their own teaching are based on research on what is known about learning and best practices to encourage learning. These include conducting frequent and formative assessments, setting learning goals that inform course structure and activities, and connecting course content to civic issues.

Approach: Community of Practice

A community of practice that includes educators, administrators, and students has developed and grown around the principal of connecting course content to unsolved, complex civic issues, answering the "why?" question so many students ask of the STEM concepts they learn, and making the learning relatable to real world applications. Membership in a community connects people and reinforces behaviors, so that membership in the SENCER community of practice reinforces those approaches that improve student learning by connecting course content to real world issues, and invigorates individual or team efforts despite the hard work involved to make these changes. Educators who have adjusted their courses and programs to reflect the SENCER ideals have noted that teaching in this way often takes more work, but the results in student learning, confidence, and interest are overwhelmingly rewarding. Program staff and volunteer leaders support this community and its growth through a variety of initiatives, resources, and symposia.

Implementation: How It Happens

SENCER symposia, both regionally and nationally, provide sessions on best practices in course design, use of formative assessment, and examples of campus implementations from both a content (disciplinary) perspective as well as which civic issues courses and programs are built around. The annual SENCER Summer Institute is team-based and residential, generally for four to five days, and focuses on pedagogy. Experts in the science of learning, course design, and assessment are brought in to present general sessions, facilitate workshops, and lead small group sessions. Campus implementation presentations allow members of the community to present the results of their work and demonstrate their expertise in these methods as well. Regional meetings, workshops, and local consultations complement national meetings, and everyone who participates in a SENCER national meeting receives updates bi-weekly on program initiatives by email. SENCER also issues small sub-awards following a competitive review process to support implementation of campus faculty development series, course revisions, and course/program development.

SENCER also offers online resources at www.sencer.net to encourage scholarship, assessment, and goal-setting. The peer-reviewed model series and online journal recognize and promote quality work in course design, civic connections, and assessment. These resources are freely available. The assessment section of the website features sections on both goal setting and formative assessment, and provides a link to the SENCER-SALG, a tool that educators can use to measure students' estimation of their learning gains through pre- and post-tests. SENCER initiatives on the scholarship of teaching and learning promote faculty research into learning, and the sharing of such research, case studies, and campus reports with members of the community of practice, disciplinary societies, and other education associations.

SENCER Assessment

SENCER Assessment Approach

The prior sections describe SENCER program methods to encourage change in pedagogical practice to improve undergraduate student learning with a focus on how to make STEM education real, relevant, rigorous, and responsible. An assessment plan can determine how much, or if, change is influenced by SENCER program participation. Looking at the role of assessment in the SENCER program it is useful to think about the multiple principles involved in student learning that need to be addressed and how to use multiple assessment sources to find out the status of meeting SENCER objectives.

Assessment Tools and Practice

The SENCER program affords an opportunity to review the principles and actions recommended in the 2003 NCR report. Overall, SENCER follows general assessment principals related to student learning and provides the training, tools, and encouragement for program participants to practice assessment. The SENCER website offers a convenient resource for several core assessment needs: (1) the SENCER Rubric; (2) methods to establish learning goals; and (3) the SENCER Student Assessment of Learning Gains (SALG). Other chapters in this book focus on the SALG (*30*, *31*).

Briefly, these core assessment resources are described as follows:

SENCER Rubric

The rubric outlines various elements of course design, faculty practice, and institutional policy making that program participants can use for assessment by looking at relevant course materials, such as syllabi, texts, websites, assignments, completed projects and tests, assessment findings, video/audiotapes, reports, journals, transcripts of interviews with students and professors, etc.

Setting Learning Goals

The SENCER program addresses the challenge of developing measurable learning goals. Presentations such as those by Barbara Tewksbury introduce SENCER participants to "the art of setting learning goals" (*32*).

SENCER-Student Assessment of Learning Gains (SALG)

The primary purpose is to provide instructors with useful, formative feedback to faculty to improve their teaching. Students do a pre and post assessment of class activities. In addition, it provides a national assessment of the SENCER program.

In addition to these core assessment resources, SENCER also conducted program participant and student surveys. The *Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project* describes the SENCER program evaluation that focused on students and the development and validation of the SALG survey instrument (*33*). This research used multiple evaluation sources similar to what the NRC report suggested and summarized in Table 2, such as a survey and interviews with 135 faculty teaching SENCER courses, on-site observations, and reviews of course materials.

SENCER models the practice of conducting formative assessment in the evaluation of symposia, programs, and resources. These assessments are conducted at the program level, course/team level, and the individual level. Symposia participants are encouraged to complete review forms that include rating scales and open-ended questions. Analyses of the responses are broken down by participant category to clarify the effectiveness of activities relative to each type of participant. Critiques and recommendations are used in planning for future symposia. For example, comments on evaluations of annual Washington Symposia have helped develop programming designed specifically for students that is distinct from faculty sessions. Summer Institute evaluations have led to changes in the format of the program schedule – leading to new sessions for hands-on activities and group discussions, influencing selections of plenary speakers, and providing workshop topics.

Surveys of community members at large are also conducted, such as the 2010 SENCER Impact Assessment Survey described in the next section of this chapter. Additionally, SENCER surveys members of specific sub-sections of the community, such as recipients of sub-grants, and the SENCER Leadership Fellows.

A survey on social media and technology use informed changes to the SENCER website implemented in early 2012, the addition of twitter feeds and a facebook page, and plans to utilize other technologies over the next several years. The survey was sent to the SENCER eNews readership (just over 2000 readers at the time), and the goal was to find out which social media applications readers already used, as well as how they were interested in accessing SENCER resources though online technologies. Results showed, for example, that our sample tended to be more likely to use Facebook frequently (67%) than LinkedIn, twitter, or tumblr. Many (78%) use YouTube, which is useful to know should we have the capability to produce videos on campus adaptations. We might also post videos of our symposia. We've also developed a private Facebook group to facilitate communication among SENCER Leadership Fellows. Knowing that 55% of our respondents use smart phones or iPads to access the internet reinforced our intention to implement a site design that scaled up and down easily on various devices. Webinars were rated overwhelmingly positively (75%), informing a collaboration launched in 2012 with Magna Publications to develop webinars on issues of course design and implementation. These webinars will be launched in summer 2012.

While our sample did not note using twitter as a primary way to communicate with faculty in our community, we did decide to begin a twitter feed as a way to reach out to other organizations regionally and nationally and to disseminate our resources. The feed, which is just under two years old, has been successful in facilitating connections to other national organizations and increasing visibility of our resources and symposia.

In 2010 the SENCER Impact Assessment Survey was designed to find out from all program participants whether or not SENCER was meeting its objectives and to use this information for future planning (*34*, *35*).

SENCER Impact Assessment: Did Participation Make a Difference?

The SENCER program is expected to encourage participant change in pedagogical practice in multiple ways as described above. To assess how, or if, participation has had an influence, we conducted the 2010 SENCER Impact Assessment Survey. The 1,685 SENCER program participants who attended at least one national or regional event between 2001 and 2010 were contacted by email to participate in a web-administered survey conducted between October 13 and November 30, 2010.

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

The 70 item comprehensive questionnaire covered SENCER program experiences, influence of SENCER on teaching, course design, student learning, and institutional impact. As suggested in the 2003 NRC report: "Self-reports and self-reflections on an instructor's teaching and promotion of student learning can be important sources of information for evaluating a teacher's effectiveness" (*36*).

For this discussion we focus on the survey data that illustrate how the SENCER experience influenced participants' actions in course management and assessment and what participants perceived to be changes in their pedagogical practice that went beyond the "usual" focus on the substantive information for their discipline.

SENCER Influence on Course Goals and Assessment

To find out more about SENCER influence on setting course objectives and assessment, the questionnaire asked: How much has your participation in SENCER contributed to: (1) setting learning goals for your courses and (2) utilizing formative assessment – a great deal, some, not much, or not at all.

Overall, more than 3 in 4 respondents said SENCER participation contributed a great deal or some to setting learning goals for their courses (88.5%) and utilizing formative assessment strategies (upgraded tasks that prove understandings) (76.9%) (Table 3).

The more SENCER events a respondent attended the more likely he or she was to say participation contributed a great deal or some:

Table 3. SENCER Participation Contributions to Setting Course Objectives and Assessment (A Great Deal/Some)

		Number of SENCER Events Attended			*Role on Campus*	
Course Planning and Assessment	*Total (n=497)*	*1-2 (n=265)*	*3-6 (n=170)*	*More than 6 (n=60)*	*Faculty (n=339)*	*Academic Admin-istrator (n=159)*
Setting learning goals for your courses	88.5	82.5	95.2	96.6***	89.9	88.0
Utilizing formative assessment strategies (upgraded tasks that prove understandings)	76.9	69.1	84.3	89.8***	75.9	79.6

Source: 2010 SENCER Impact Assessment Survey.
Note: Due to item nonresponse, the number answering each of these items varied. The numbers on the table represent the maximum of the following ranges: Total 497-481; Number of SENCER events: 1-2 events 265-256; 3-6 events 170-165; more than 6 events 60-58; Role on Campus: Faculty 339-335; Not Faculty 159-145. This analysis excludes missing data and not applicable responses.
Note: Pearson Chi -Square significance test.
*P<0.01.
**P<0.001.
***P<0.0001.

Attended More Than Six Events

The contribution of SENCER participation to setting learning goals for courses was close to unanimous (96.6%) while somewhat fewer reported a great deal or some contribution to utilizing formative assessment strategies (89.8%).

Attended Three to Six Events

This group of event attendees is similar to the more than six event participants. Their report on the contribution of SENCER participation on setting learning goals for courses was 95.2% while somewhat fewer reported a great deal or some contribution to utilizing formative assessment strategies (84.8%).

Attended One or Two Events

Fewer among these attendees report SENCER participation contributed a great deal or some to setting learning goals for courses (82.5%), and about 7 in 10 (69.1%) reported a contribution to utilizing formative assessment strategies (84.8%).

Overall, no matter what their role on campus, close to 9 in 10 SENCER participants perceived a contribution to setting learning goals for courses: faculty members (89.9%); academic administrators (88.0%). While somewhat fewer of both groups attributed SENCER participation to utilizing formative assessment strategies, academic administrators (79.6%) were somewhat more likely than faculty members (75.9%) to report a great deal or some SENCER influence.

Influence on Student Learning Opportunities

We also found out what SENCER participants perceived as the programs influence on their pedagogical practice. SENCER participants were asked to strongly agree, agree, disagree, or strongly disagree if participation in program activities increased student learning opportunities to: (1) make connections between science and civic problems/topics; and (2) make interdisciplinary connections (Table 4).

Overall, participants were almost unanimous in their perception that their SENCER experience increased student opportunities to make connections between science and civic problems/topics (95.2%) and to make interdisciplinary connections (94.7%). The more SENCER events a respondent attended the more likely he or she was to strongly agree or agree that SENCER participation influenced these pedagogical practices:

Attended More Than Six Events

There was unanimous agreement that SENCER had an influence on increasing student opportunities to make connections between science and civic problems/topics (100%) and to make interdisciplinary connections (100%).

Attended Three to Six Events

The perception that SENCER had an influence on pedagogical practice to make interdisciplinary connections (100%) was unanimous and almost unanimous in the perception that it had increased student opportunities to make connections between science and civic problems/topics (98.7%).

Attended One or Two Events

Nine-in-ten of these attendees report pedagogical practice being influenced by SENCER participation to: make connections between science and civic problems/topics (91.7 %) and make interdisciplinary connections (91.4 %).

Overall, while no matter what their role on campus, 9-in-10 SENCER participants perceived an influence on pedagogical practice, those who are academic administrators compared to those who are faculty member were more likely to agree on SENCER influence. Administrators were almost unanimous on the influence to increase student opportunities to make interdisciplinary connections (98.0 %) and connections between science and civic problems/topics (97.9 %). In comparison, slightly fewer faculty agreed SENCER participation influenced connections between science and civic problems/topics (93.9 %) and increased student opportunities to make interdisciplinary connections (93.1%).

Table 4. SENCER Influence on Pedagogical Practices To Increase Student Opportunities (Strongly Agree/Agree Percentages)

		Number of SENCER Events Attended			***Role on Campus***	
Pedagogical Practice	*Total (n=485)*	*1-2 (n=256)*	*3-6 (n=168)*	*More than 6 (n=60)*	*Faculty (n=332)*	*Academic Admin-istrator (n=153)*
Make connections between science and civic problems/topics	95.2	91.7	98.7	100***	93.9	97.9
Make interdisciplinary connections	94.7	91.4	100	100***	93.1	98.0*

Source: 2010 SENCER Impact Assessment Survey.
Note: Due to item nonresponse, the number answering each of these items varied. The numbers on the table represent the maximum of the following ranges: Total 485-401; Number of SENCER events: 1-2 events 256-211; 3-6 events 168-138; more than 6 events 60-48; Role on Campus: Faculty 332-279; Not Faculty 153-122.
Note: Pearson Chi-Square significance test.
*P<0.01.
**P<0.001.
***P<0.0001.

Survey responses provide evidence that SENCER is achieving its goals of influencing participant pedagogical practice to connect course content to real world issues, and to incorporate best practices emerging from cognitive science research into teaching methods. Sustained engagement and continuing participation in SENCER symposia and connection to the community of practice increase the likelihood educators will utilize these methods, and will provide their students opportunities to make interdisciplinary connections and link their course work with its real world applications. Survey respondents also convey that involvement with SENCER has led to substantial course and program development. These results illustrate the effectiveness of SENCER program participation.

Conclusion

SENCER has incorporated the research about and best practices known about STEM pedagogy to develop an approach that can transform undergraduate education. Using the guidelines outlined in the nine principals for student learning, SENCER has a dynamic approach that integrates assessment and uses data to enhance participant program experiences and make on-going adjustments to improve the approach to undergraduate STEM instruction. These data come from a variety of sources—practitioner published results of campus interventions influenced by SENCER, SALG course specific and national results, SENCER symposia, program, and resource evaluations, and participant self-reports and reflections.

While the data from various sources are overwhelmingly positive in terms of the impact SENCER has had in reaching educators and facilitating the use of best practices to improve student learning, responses also let us see that while use of best practices is at an incredibly high level for those who have participated in SENCER programs, there are still educators who have yet to incorporate formative assessments and set learning goals. This speaks to a continued need for SENCER to provide quality faculty development programs that convey effective learning methods to participants.

References

1. *Quantitative Reasoning for College Graduates: A Complement to the Standards*; The Mathematical Association of America, 1998. http://www.maa.org/past/ql/ql_toc.html.
2. *Scientific Foundations for Future Physicians*; AAMC–HHMI Joint Committee, Association of American Medical Colleges: Washington, DC, 2009.
3. Brewer, C., Smith, D.; Eds.; *Vision and Change in Undergraduate Biology Education: A Call to Action*; American Association for the Advancement of Science (AAAS): Washington, DC, 2011.

4. Deeds, D. G.; Allen, C. S.; Callen, B. W.; Wood, M. D. A new paradigm in integrated math and science courses: Finding common ground across disciplines. *J. Coll. Sci. Teach.* **2000**, Nov, 178–183.
5. Lynd-Balta, E.; Erklenz-Watts, M.; Freeman, C.; Westbay, T. D. Professional development using an interdisciplinary learning circle. *J. Coll. Sci. Teach.* **2005**, Dec, 18–24.
6. Nava-Whitehead, S. M.; Augusto, K. W.; Gow, J. B. Bewitching ideas influence learning: An evaluation of an interdisciplinary teaching experience. *J. Coll. Sci. Teach.* **2011**, *40*, 65–69.
7. *Bio 2010: Transforming Undergraduate Education for Future Research Biologists*; National Research CouncilNational Academies Press: Washington, DC, 2003.
8. Kosal, E.; Lawrence, C.; Austin, R. Integrating biology, chemistry, and mathematics to evaluate global water problems. *J. Coll. Sci. Teach.* **2010**, *40*, 41–47.
9. Chekuri, N. R.; Gilbert, Z.; Johnson, K.; Kantak, A.; Tippens, M. Preparing students for a transdisciplinary approach to solving a complex problem. *Science Education and Civic Engagement, An International Journal* **2012**, *4*, 43–54.
10. Wagstrom, R. B. Teaching pre-college algebra mathematics through environmental sustainability: Curriculum development and assessment. *Science Education and Civic Engagement, An International Journal* **2010**, *2*, 17–23.
11. Pfaff, T. J.; Erkan, A.; Hamilton, J. G.; Rogers, M. Multidisciplinary engagement of calculus students in climate issues. *Science Education and Civic Engagement, An International Journal* **2011**, *3*, 52–56.
12. FitzPatrick, K. Learning public health through civic issues. *Science Education and Civic Engagement, An International Journal* **2012**, *4*, 66–79.
13. Duschl, R. A.; Schweingruber, H. A.; Shouse, A. W. *Taking Science to School: Learning and Teaching Science in Grades K-8*; The National Academies Press: Washington, DC. 2007.
14. Nava-Whitehead, S. M.; Augusto, K. W.; Gow, J. B. Bewitching ideas influence learning: An evaluation of an interdisciplinary teaching experience. *J. Coll. Sci. Teach.* **2011**, *40*, 65–69.
15. Kim, B. S.; Szpunar, D. E. Integrating teaching experience into an introductory chemistry course: The chemistry of global warming. *Science Education and Civic Engagement, An International Journal* **2010**, *2*, 35–40.
16. Fink, M. L. Preparing future teachers using a SENCER approach to positively affect dispositions toward science. *Science Education and Civic Engagement, An International Journal* **2009**, *2*, 14–21.
17. *Evaluation and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics*, National Research Council, 2003. http://www.nap.edu/catalog/10024.html.
18. Astin, A. W.; Banta, T. W.; Cross, P. K.; El-Khawas, E.; Ewell, P. T.; Hutchings, P.; Marchese, T. J.; McClenney, K. M.; Mentkowski, M.; Miller, M. A.; Moran, E. T.; Wright, B. D. *Assessment Forum: Nine Principles of Good Practice for Assessing Student Learning*, 1996.

http://www.lorainccc.edu/NR/rdonlyres/5C88727B-2AB4-4D18-B481-D0EDFB95706A/476/9AssessmentPrinciples.pdf.

19. Smith, G. How does student performance on formative assessments relate to learning assessed by exams? *J. Coll. Sci. Teach.* **2007**, 28–34.
20. McGuire, T. *Reinventing Myself As a Professor: The Catalytic Role of SENCER*, 2005. http://serc.carleton.edu/sencer/backgrounders/reinventing_myself_professor.html.
21. Donovan, M. S., Bransford, J. D., Pellegrino, J. W., Eds.; *How People Learn: Bridging Research and Practice*; National Research Council: Washington, DC, 1999.
22. Black, P.; Wiliam, D. Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice* **1998**, *5*, 7–74.
23. Black, P.; Wiliam, D. Inside the black box: Raising standards through classroom assessment. *Kappan* **2010**, *92*, 81–90(reprint of *Phi Delta Kappan.* 1998, *80*, 139−144, 146−148).
24. Deslauriers, L.; Schelew, E.; Wieman, C. Improved learning in a large enrollment physics class. *Science* **2011**, *332*, 862–864.
25. Smith, G. How does student performance on formative assessments relate to learning assessed by exams? *J. Coll. Sci. Teach.* **2007**, 28–34.
26. Straits, W. J.; Wilke, R. R. Practical considerations for assessing inquiry-based instruction: Some guidelines for improving student assessment. *J. Coll. Sci. Teach.* **2002**, *XXXI*, 432–435.
27. Ludwig, M. A.; Bentz, A. E.; Fynewever, H. Your syllabus should set the stage for assessment for learning. *J. Coll. Sci. Teach.* **2011**, *40*, 20–23.
28. Simon, B.; Taylor, J. What is the value of course-specific learning goals? *J. Coll. Sci. Teach.* **2009**Nov, 52–57.
29. Chasteen, S. V.; Perkins, K. K.; Beale, P. D.; Pollock, S. J.; Wieman, C. E. A thoughtful approach to instruction: Course transformation for the rest of us. *J. Coll. Sci. Teach.* **2011**, *40*, 24–30.
30. Jordan, T. Using the SENCER –SALG to reveal student learning in a large-scale environmental science course for non-majors, 2012, in press.
31. Carroll, S.; Odenbrett, G. C. From SALG to GLISTEN: Scaling up assessment of student learning, 2012, in press.
32. Tewksbury, B. On the Cutting Edge. http://serc.carleton.edu/NAGTWorkshops/index.html.
33. Weston, T.; Seymour, E.; Thiry, H. *Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project*; University of Colorado: Boulder, CO, 2006. http://www.sencer.net/Assessment/pdfs/FINAL_REPORT_SENCER_12_21_06.pdf.
34. Ballou, J. 2010 SENCER Impact Assessment Survey: Summary of Results. http://serc.carleton.edu/sencer/newsletters/52534.html.
35. Ballou, J. Reshaping how educators view student STEM learning: Assessment of the SENCER experience. *Science Education and Civic Engagement, An International Journal* **2012**, *4*, 27–36.
36. Hutchings, P., Ed.; *The Course Portfolio: How Faculty Can Examine Their Teaching To Advance Practice and Improve Student Learning*; American Association for Higher Education: Washington, DC, 1998.

Chapter 13

Using the SENCER-SALG To Reveal Student Learning in a Large-Scale Environmental Chemistry Course for Non-Majors

Trace Jordan*

Associate Director, Morse Academic Plan, New York University, New York, New York 10003
***E-mail: trace.jordan@nyu.edu. Phone: 212-998-8078.**

Publication Date (Web): December 18, 2012 | doi: 10.1021/bk-2012-1121.ch013

The SENCER-SALG is an online assessment instrument that is aligned with the educational goals of the SENCER project. It is based on the same principle as the original SALG (Student Assessment of Learning Gains), which shifts the focus away from the course instructor and asks students to self-assess their own learning gains. The SENCER-SALG instrument contains a set of survey questions about content knowledge, skill development, interest in science, and civic engagement. In addition to the core questions, it also permits the instructor to customize the survey by adding questions that address specific course goals. This chapter describes my implementation of the SENCER-SALG during four semesters of a large-scale environmental chemistry course at New York University and examines what the assessment data reveal about student learning. In the spirit of knowing one's tools, I begin with an analysis of the SENCER-SALG instrument within the broader context of research on student self-assessment.

Introduction

This chapter describes the implementation and analysis of the SENCER-SALG as an assessment instrument for a large-scale introductory environmental chemistry course for non-majors. The SENCER-SALG is a modified version of a well-established assessment survey called the Student Assessment of Learning

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Gains (SALG) and contains adaptations designed to address the SENCER ideals of teaching and learning science through a focus on complex civic issues and use of student-centered pedagogy (*1–3*). I have employed the SENCER-SALG as a pre/post assessment during four semesters of teaching a course entitled *Energy and the Environment* at New York University (NYU), with a class size of 120 students per semester. This extended use and large enrollment have provided a rich source of information about students' responses to a range of SENCER-SALG questions that query their knowledge, confidence, attitudes, and perspectives on effective pedagogies. The content of the chapter will focus on three questions:

- Why use the SENCER-SALG as an assessment instrument?
- How do I use the SENCER-SALG in *Energy and the Environment?*
- What does the SENCER-SALG reveal about student learning?

Why Use the SENCER-SALG as an Assessment Instrument?

Discussion of "assessment" is all the rage in higher education (*4*, *5*), yet the topic still elicits discomfort and confusion for most faculty instructors in the sciences. While many instructors are eager to find out what students are learning from their courses, they are unsure about how to obtain this information outside the traditional testing strategies of quizzes, homework, and examinations. Institutional imperatives for collecting assessment data are often driven by external necessities such as review by accrediting agencies, but these institution-wide approaches to assessment strike many professors as being far removed from their day-to-day practices in the classroom. Making assessment more accessible, transparent, and meaningful to faculty instructors will help them integrate it more effectively into their standard educational practices.

The SENCER-SALG is a widely-used resource for assessment that provides faculty members with feedback on questions that are directly relevant to their educational mission: What are my students learning? What components of the course design (assignments, teaching strategies, etc.) were most effective in helping my students learn? What skills do my students feel confident they have mastered, and where do they still feel under-prepared? Has my course sparked their interest in the subject, perhaps to the point of taking follow-up courses? Do students understand the connection between science and civic issues, and has this insight prompted them to take some form of civic action? I began using the SENCER-SALG in 2006 as an outcome of my longstanding involvement with the SENCER project and my regular participation in the annual SENCER Summer Institutes. I now use this assessment tool every semester for all of my non-majors science courses at NYU. This in-depth analysis of SENCER-SALG data from *Energy and the Environment* was prompted by my selection as a SENCER Leadership Fellow.

Development of the SENCER-SALG

If instructors are currently using the SENCER-SALG, or plan to use it in the future, then we should learn more about it – what are its origins, strengths, and limitations? The development of the SALG instrument and its later derivatives has been thoroughly described by Stephen Carroll in a previous ACS symposium volume—*Science Education and Civic Engagement: The SENCER Approach* (*6*). In brief, the original SALG was first was designed in 1997 by Elaine Seymour at the University of Colorado at Boulder, with the goal of collecting evidence of student learning in two innovative projects in undergraduate chemistry education. The SALG was organized on the principle of asking students to self-assess what features of the course (lectures, group work, labs, etc.) helped their learning, increased their understanding, and developed their skills. The SALG was subsequently converted from its paper version to an online format, which streamlined the submission of student responses and facilitated the presentation of statistical summary data (*7*). In 2003, when the SALG methodology was adopted as the primary assessment strategy for the SENCER project, Seymour and colleagues developed a modified assessment survey known as the SENCER-SALG. This new instrument included a baseline survey (pre-test), designed to be answered by students at the beginning of the semester, and a set of core questions that were aligned with SENCER's pedagogical goals and desired student outcomes. Both the SALG and the SENCER-SALG were later updated by the SALG Development Group to create 2.0 versions, which now include a streamlined web interface, user-friendly tools for easier survey design, and expanded assessment tools such as cross-tabulation analysis and text coding features. Obtaining precise numbers on total usage of the SALG and SENCER-SALG is complicated by the different versions of the instrument, including the early paper-based forms. At the time of writing this chapter in May 2012, approximately 5,500 - 6,000 instructors have used the SALG and 175,000 - 200,000 students have completed a SALG survey. For the SENCER-SALG, approximately 125 faculty have used this instrument to survey around 16,000 students (*8*).

A complete list of questions for the SALG and SENCER-SALG surveys is provided in the Appendices of Carroll's chapter (*6*). The design of these survey items is markedly different from the types of questions used in standard course evaluation forms, which typically focus on the actions of the professor (e.g., Was the instructor well prepared? Were the lectures clearly organized?) . The wording of traditional course evaluations often implies that any learning within the course is the sole responsibility of the instructor and demotes students to having only a passive role in their own learning experiences. By contrast, the methodology of the SALG and SENCER-SALG shifts the focus away from the instructor and asks students to shine a self-reflective spotlight on their learning.

Validity and Reliability of the SENCER-SALG

An assessment instrument is usually evaluated according to two criteria – *validity* and *reliability*. An instrument is valid if it actually measures what it is supposed to measure, and it is reliable if it yields consistent results when used repeatedly under the same conditions. These psychometric properties of the SENCER-SALG have been analyzed by Weston, Seymour and co-workers (*9*, *10*). One of these studies (*9*) used an aggregate data set composed of 55 instructors, 213 courses, and 7,091 students. The courses spanned a range of scientific disciplines with the largest proportions being biology courses (40%) or interdisciplinary (38%) courses. Questions within the SENCER-SALG survey are organized into three categories (or sub-scales) that reflect the core educational principles of SENCER – *confidence in science skills*, *interest in science*, and *civic engagement*. The authors examined the distribution of student responses to the survey items and observed a normal range of variation within the Likert scale, without obvious floor or ceiling effects. An exception was found for some items within the "civic engagement" category, where only a very small number of students had participated in public civic actions like writing a letter to an editor or attending a community meeting. Each sub-scale showed high internal reliability on the pre- and post-tests—the value of Cronbach's α (a standard reliability coefficient) was greater than 0.80 for all subscales with the exception of the *civic engagement* scale in the pre-test (α = 0.73).

When evaluating the validity of the SENCER-SALG, one important question to consider is whether students are answering the questions appropriately or whether the feedback is distorted. One potential threat to validity is *reporting bias*—are students reporting their actual opinions or are they telling us what they think we want to hear? If a respondent's answers to survey questions are skewed to be more "socially acceptable," such as inflating self-reported interest in a course to convey a positive impression to an instructor, the effect is known as *social desirability bias* or *socially desirable reporting*. Not surprisingly, the evidence for or against reporting bias is often ambiguous and is usually context dependent. For example, a recent meta-analysis of research studies on this topic (*11*) revealed that some job applicants displayed socially desirable reporting bias in their self-assessment of workplace abilities, yet there was no evidence of biased reporting in general personality assessments where there was no threat of embarrassment or obvious motivation for misrepresentation. Within an educational context, an investigation (*12*) of students' self-reporting of their SAT and ACT scores found that inaccurate reports contained a disproportionate number of over-estimates, and that lower-achieving students are less accurate in reporting their scores; both of these results are consistent with social desirability bias. However, Kuh and colleagues (*13*) use psychometric data from the *College Student Report*—which is part of the *National Survey of Student Engagement*—to argue that student self-reports are valid provided that careful attention is given to the content and phrasing of survey questions.

The SENCER-SALG is designed to minimize the risk of reporting bias by ensuring that all student responses remain anonymous. Students log onto the SALG-SITE using an identifier such as their e-mail or student ID, and the SALG website provides a list of these identifiers after students complete the survey. However, specific survey responses are not associated with student identifiers; when a report of survey results is generated, student responses are encoded through the use of untraceable ID numbers. This system provides an environment in which students can express their genuine opinions without any apprehension of negative consequences. Because of the anonymity of the SENCER-SALG, giving course credit for the assignment should also have no impact on the accuracy of students' responses.

Probably the most common question that classroom instructors ask about using the SENCER-SALG is the degree to which students' self-reports of learning gains are correlated with direct measures of their performance on exams or other course assignments. This issue of *criterion validity* was investigated using 10 sections of a chemistry course (N = 365) at a large public university (*9*). Comparing students' responses to SENCER-SALG items with their test scores showed moderate correlation ($r = 0.27$) between the *interest in science* sub-scale and the test result, but the *confidence* and *civic engagement* sub-scales had zero correlation to test scores. The results of an earlier study using the SALG (not the SENCER-SALG) in an astronomy course (N = 119) showed a stronger correlation ($r = 0.41$) between aggregate survey responses and students' final exam score on a multiple choice test. However, students were inconsistent in self-rating their understanding of specific course topics (such as stellar evolution), and the correlation between topic-based SALG ratings and related exam questions ranged between $r = 0.49$ and zero.

The question of how much students' self-assessment of their learning gains correlates (or doesn't) with direct measures of their performance on exams or other course assignments is worth exploring in more detail because it is more nuanced than it initially appears. The educational research literature on self-assessment typically focuses on the level of agreement between students' self-reporting of the quality of their assignments and teachers' evaluation of the same assignments (*14–18*). For example, Falichikov and Boud performed a meta-analysis of research studies that focused on "comparison of grading by experts (faculty, instructors, teachers) and those by students" *((15), p. 398)*. When analyzing the composite results of 52 published research studies, the authors discovered a wide variation in the extent of agreement between students and instructors. The correlation coefficient (r) between student and instructor grading ranged from -0.05 to 0.82, with a mean value of 0.39. Despite this variability, the authors were able to identify some factors that affected the accuracy of student self-assessment—in general, students' self-assessment of their own work was more similar to instructor ratings when students were enrolled in an advanced course or when the course was "within the broad area of science." However, closer examination of the research studies included in this meta-analysis reveals that all studies classified as "science" were performed in areas of professional training such as engineering, medicine, nursing, dentistry, and diatetics; in fact, many of these studies were assessments of performance in a clinical environment (e.g., evaluation of first year medical residents). This observation limits the applicability of the conclusions to undergraduate science courses.

A search of the ERIC educational database (*http://www.eric.ed.gov/*) reveals only a small number of educational studies that examine student self-assessment in college level science courses (*19–25*). These studies vary widely in their scope so it is difficult to extract any generalizations. However, one useful insight from the two studies by Zoller and colleagues (*20*, *21*) is that students' self-assessment of their question responses shows a close match to instructor ratings for lower-order cognitive skills but deviate significantly for questions that require higher-order cognitive skills.

While these findings on self-assessment provide interesting context, we must remember that the SENCER-SALG does *not* purport to provide a summative assessment of students' knowledge and skills at the end of the course. Instead, the SENCER-SALG aims to reveal student learning gains and what features of a course (content, readings, pedagogy, etc.) contributed to those gains. In other words the SALG looks at both *what* and *how* students learn, whereas the *how* is missing from direct measures. Students who report significant learning gains from a course may not necessarily be those with the best final exam scores. Some students who enter a science course with minimal background in the subject may learn a tremendous amount during the semester, but their final exam scores may still not be strong compared other students. By contrast, high-achieving students who achieve good exam scores and course grades may enter the course with considerable prior knowledge (perhaps gained from AP courses in high school), so their learning gains between the beginning and end of the course may be relatively small. Traditional course evaluations of student learning, which measure only student performance at the "finishing line," cannot distinguish between students who knew almost everything on the first day of class and those who made significant learning gains during the semester. In addition, the SENCER-SALG also aims to reveal issues of student interest, confidence, engagement, motivation, and civic engagement…none of which are assessed by direct measures of student performance on exams or other course assignments. It is well known that introductory science courses can be off-putting for many students, which contributes to the large degree of attrition among self-declared STEM majors (*26*, *27*). Stimulating student interest in science through real-world issues in the curriculum and student-centered pedagogies in the classroom or field site is a core mission of the SENCER project. The SENCER-SALG can reveal whether students have developed positive attitudes about science and what aspects of the course were most effective at promoting these changes.

We can summarize these points with one key observation—the SENCER-SALG survey and traditional course assignments (exams, homeworks, etc.) are *different types of assessment* that measure different aspects of student learning. Each of these assessments is useful and informative within its own domain. For this reason, college instructors should view the SALG as a *complementary assessment strategy* that does not seek to replicate or replace direct assessment but can be used alongside these measures as part of a multifaceted "thick description" of teaching and learning (*28*, *29*).

How Do I Use the SENCER-SALG in Energy and the Environment?

Educational Context

In 1995 NYU established a new general education curriculum named the Morse Academic Plan (MAP) in honor of Samuel F.B. Morse, an early faculty member who was both an artist and inventor. The MAP curriculum provides the core general education experience for undergraduate students enrolled in most of NYU's undergraduate divisions, including the College of Arts and Science, the Leonard K. Stern School of Business, the Tisch School of the Arts, and the Steinhardt School of Culture, Education and Human Development. In addition to longstanding requirements in expository writing and foreign language, the MAP added two new course sequences – *Foundations of Contemporary Culture* (humanities, arts, and social sciences) and *Foundations of Scientific Inquiry* (mathematics and natural sciences) (*30*). The latter sequence consists of three courses—*Quantitative Reasoning*, *Natural Science I* (physical science) and Natural Science II (life science)—that are offered in different versions, thereby allowing students to select and study the topic they find most appealing (*31*). For example, *Quantitative Reasoning* includes courses that apply mathematical reasoning to the natural and social sciences, in addition to a new course called *Great Ideas in Mathematics* that provides an accessible introduction to selected concepts in pure mathematics. The *Natural Science I* courses include *Energy and the Environment* (the focus of this chapter), *Einstein's Universe*, *How Things Work*, and *Quarks to Cosmos*. To complete the sequence, the course offerings for *Natural Science II* include *Human Genetics*, *Brain and Behavior*, *Human Origins*, *Molecules of Life*, and *Lessons from the Biosphere*.

These general education courses are taken by undergraduate students who are pursuing majors in arts, humanities, social science, business, and education; students who select a major in science or engineering, or who are fulfilling the pre-medical curriculum, enroll in the standard introductory courses in calculus and the various science disciplines. Each MAP course provides biweekly lectures taught by full-time NYU faculty, including some of the university's most distinguished teachers and researchers, with class sizes that range from 80 – 160 students. All courses also include a weekly small-group session taught by a graduate student; for the *Natural Science* courses, this session is a 1 hour 40 minute laboratory period in which students perform experimental investigations that reinforce and extend the lecture topics. The pedagogy and curriculum design of the MAP sciences courses are self-consciously different from departmental courses. Their goal is not to provide the same breadth of coverage as an introductory course in physics, chemistry, or biology; instead, each MAP course focuses on a specific scientific topic in order to provide students with insights into how scientists explore the natural world. The content for each course aims to strike a balance between foundations and frontiers, giving students a solid base of scientific principles and then showing how they are applied to cutting-edge topics such as dark matter, the Higgs boson, climate change, the neuroscience of behavior, and threats to biodiversity. Whenever possible, MAP science courses

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

explore the interrelation between scientific knowledge and its social, ethical, and political dimensions, which includes issues such as stem cell research and the politics of climate change.

Course Goals and Content

Energy and the Environment is offered each semester in two lecture sections taught by different faculty instructors, each with an enrollment of 120 students; the course attracts a total of 480 students per academic year, which constitutes the largest enrollment within the *Foundations of Scientific Inquiry* curriculum. *Energy and the Environment* focuses on the chemical foundations of environmental issues since another MAP course (under the *Natural Science II* rubric) examines ecology, evolution, and biodiversity. It was selected as a SENCER Model Course in 2002 (*32*) and was featured in an article on chemistry education and civic engagement that appeared in the *Journal of Chemical Education* (*33*). Readers interested in other examples of non-majors chemistry courses that use a civic engagement pedagogy are encouraged to consult the following articles, book chapters, and SENCER model courses (*34–40*).

The student learning goals for my section of *Energy and the Environment* are presented in Table I. The course uses *Chemistry in Context* as the primary textbook (*41*)—this text, currently in its 7th edition, pioneered an issues-driven approach to science education. The sequence of course topics is listed in Table II and follows the chapters in *Chemistry in Context*, with the exception of the chapter on nuclear power (which was omitted because of time constraints). The course uses contemporary environmental issues as a framework to introduce foundational principles in chemistry, such as molecular structure, energy from combustion, aqueous solutions, and electron transfer reactions. Each theme in the course is accompanied by related laboratory activities, mostly hands-on experiments but also including a role-playing exercise about ethanol biofuel. Students are provided with multiple opportunities for civic engagement through a variety of case studies in public policy and social justice that are integrated throughout the course (see Table III). The goal of these case studies is to foster students' abilities to become well-informed and judicious decision-makers on issues of personal and public importance (*42*). Each example includes an in-class written assignment and classroom discussion that enables students to articulate their position on a civic issue while also hearing and acknowledging differing viewpoints. For one of these topics, which examines a proposed ban on minors using indoor tanning beds, the in-class activity is extended by a homework assignment in which students write a policy letter to their local Congressional representative that argues for or against such a ban. When writing their letters, students draw on an interesting range of perspectives and evidence that include medical studies of the relationship between tanning beds and skin cancer, the role of the tanning bed industry in the local economy, and the degree to which the local or Federal Government should limit personal freedom of choice. In summary, *Energy and the Environment* aims to implement SENCER's educational ideals within a large-scale non-majors course by developing scientific literacy through active learning and student engagement with complex, unsolved civic issues.

Table I. Learning Goals for *Energy and the Environment*

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

Table II. Course Content for *Energy and the Environment*

Environmental Theme	*Chemical Principles*	*Laboratory Activity*
The Air We Breathe	Periodic table, gases, concentration, chemical reactions.	Mathematics Review Gases in a Breath
The Ozone Layer	Atoms, covalent chemical bonding, molecules, electromagnetic radiation.	Properties of Light Spectroscopy of Sunscreens
Climate Change	3D structure of molecules, molecular vibrations, moles, molar masses.	Molecular Structure and Vibrations
Energy from Combustion	Energy and thermodynamics, combustion reactions, chemical bond energies, reaction energy and catalysts.	Energy from Chemical Reactions. Biofuel Policy Role Play
Water for Life	Properties of water, ions, solutions, solubility of compounds, molar concentration.	Aqueous Ions Measuring Hard Water
Acid Rain	Acids and bases, neutralization, pH as a measure of acidity	Acid Rain Titration
Energy from Electron Transfer Reactions	Oxidation and reduction reactions, electrochemistry, semiconductors.	Building Batteries Solar Cells and Fuel Cells

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Table III. Examples of Civic Engagement Topics in Energy and the Environment

What is the relationship between air quality and increased rates of childhood asthma in the Bronx? What policy solutions do you propose to address this problem?
Should minors under 18 years of age be banned from using indoor tanning beds?
In recent years the amount of scientific evidence for global climate change has increased but U.S. opinion polls have shown a *decrease* in public perception of climate change as a potential problem. What are the origins of this mismatch between scientific evidence and U.S. public opinion?
Do you support or oppose fracking as a strategy for future U.S. energy production?
Would it be environmentally and economically beneficial to replace gasoline with ethanol biofuel?
Is it ethical for us to drink bottled water when over one billion people worldwide do not have access to clean and safe drinking water?
What size and scope of solar energy facilities would be required to supply all of NYU's energy needs?

Demographic Information

A total of 484 students were enrolled in *Energy and the Environment* during four semesters when SENCER-SALG survey data were collected (Spring 2009, Spring 2010, Fall 2010, and Fall 2011). I served as the faculty instructor for all four semesters. Within this student population, 65.5% identified as female and 34.5% as male. Slightly more than 12% of enrolled students were classified by NYU as foreign students. Students were enrolled in several different undergraduate divisions that all subscribe to NYU's general education curriculum. As shown in Figure 1, the largest student population was from the College of Arts and Science (61.2%), NYU's liberal arts division, followed by the Steinhardt School of Culture, Education, and Human Development (23.8%), which offers majors in communications, K-12 education, and various professions in human health and the arts. Students from the Stern School of Business constituted 9.5% of the course enrollment, and a total of 5.5 % were enrolled in other undergraduate programs, such as the Preston Robert Tisch Center for Hospitality, Tourism and Sports Management or the Tisch School of the Arts. Figure 2 provides the distribution of students by year of study when they began the course—sophomores (33.1%) were the largest group followed by almost equal proportions of freshmen (24.0%) and juniors (25.6%). Seniors constituted 17.3% of the course enrolment, even though we encourage students to complete their *Natural Science* requirement before their senior year.

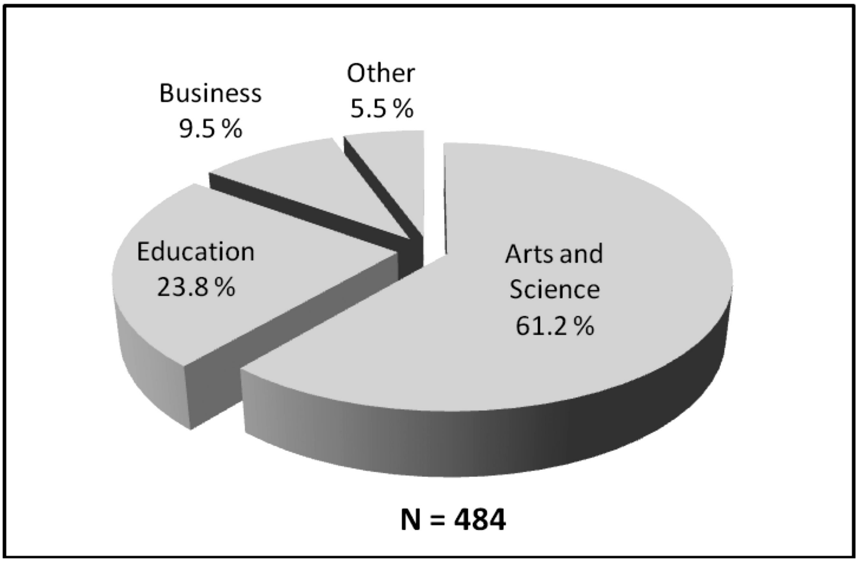


Figure 1. Student enrollment by undergraduate division within New York University.

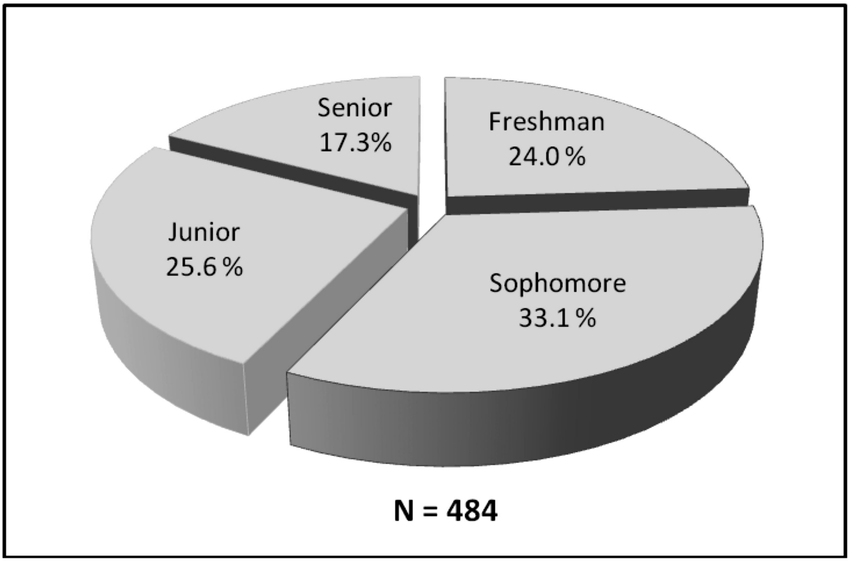


Figure 2. Student enrollment by year of study.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Assignment and Completion of SENCER-SALG Surveys

Assessment of *Energy and the Environment* was performed with a version of the SENCER-SALG instrument that included all of the core questions addressing SENCER educational goals plus some additional questions that were specific to the course. This flexibility to include instructor-designed questions alongside the core survey items is one of the most attractive features of the SENCER-SALG. Completion of the SENCER-SALG survey was integrated into the course assignments for *Energy and Environment*—students' first homework assignment was to complete the baseline survey and they received additional homework credit for completing the end-of-semester survey. Students were given a one week window to provide responses to the survey (using programmed start/end dates for the survey instrument). The SALG website provides real-time information on how many students have completed the survey, which allows instructors to monitor the survey's progress and send a reminder to students if necessary. After the conclusion of the survey, the instructor can obtain a complete list of identifiers for students who have completed the survey and give them homework credit for the assignment. The aggregate completion rate for all four semesters was 96.0% for the baseline survey and 89.0% for the end-of-semester survey. These relatively high completion rates indicate that the strategy of using homework credit was successful at motivating most students to answer the SENCER-SALG surveys.

Student Responses to the Baseline Survey

The baseline survey for *Energy and Environment* was built on the framework of the standard SENCER-SALG survey that asks students about their understanding, skills, attitudes, integration of learning, major and GPA. Course-specific questions were added that asked students to rate their initial understanding of the major environmental topics in the syllabus: air quality, global warming, fossil fuels, solar cells, etc. Although "global warming" has been superseded by "climate change" as the terminology of choice, I retained the more familiar term to preserve the consistency of survey language from semester to semester. Students selected responses on a Likert scale from "not at all" (numerical score = 1) to "a great deal" (numerical score = 5). The results for the content-based section of the survey are presented in Figure 3, where the number shown for each question is the mean score of 484 student responses. All graphs in this chapter are shown with a horizontal scale of 2.0 to 5.0 to visually highlight variation in the mean responses to different questions. Using these graphs to present student responses as a numerical mean is a convenient summary, but it elides the distribution of responses in each category, which provides more nuanced information about students' self-assessment. For this reason, further details of student responses to survey questions are provided in data tables within an Appendix to (see Table A-I for data on content questions).

The topic of "global warming" elicited the most positive student self-assessment for understanding (a mean score of 4.0 on a 5-point scale), as we might expect given the prevalence of this topic in the news media, The two runner-up topics were air quality and fossil fuels, both with a mean score of 3.7. For all three of these topics, however, students' confidence in their own understanding was not high—most responses fell into the middle-range categories of "just a little" and "somewhat," while the faction of students answering "a great deal" was always less than 20%. The least understood concepts in the list were hydrogen fuel cells and solar cells, two key technologies for alternative energy generation. For both these topics the mean scores were below 3.0 and the total proportion of students who ranked their understanding as "not at all" or "just a little" was close to 75%. These survey responses indicate that most students entered the course with a passing acquaintance of some environmental topics but not a firm understanding of them; students' self-reported understanding of renewable energy technologies such as hydrogen fuel cells and solar cells was particularly low. The baseline survey also included an open-ended response question: "What do you expect to understand at the end of the course that you do not know now?" The most frequently mentioned topics in students' answers were global warming and energy, with a particular interest in alternative/renewable energy.

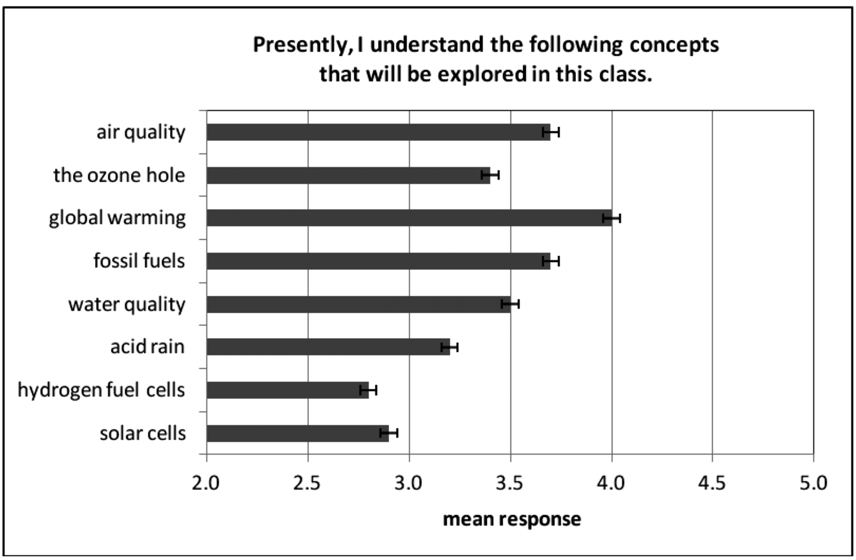


Figure 3. Student responses to SENCER-SALG baseline questions on understanding (N = 465). Bars show the mean response ± one standard error.

Students' self-reporting of their initial skills, attitudes, and integration of learning is summarized in Figures 4, 5 and 6, with more details provided in Table A-II. Most students expressed relatively high confidence in their current abilities to find sources (mean = 4.6), critically read them (mean = 4.6), recognize a sound

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

argument and use of evidence (mean = 4.7), and develop a logical argument (mean = 4.6). The combined proportion of students who answered "not at all" or "just a little" for these skills was always less than 20%. Students' enthusiasm about the subject was fairly high (mean = 4.1), but only 11% of students answered "a great deal" for this question. Students had a similar level of interest in discussing the subject with friends or family (mean = 4.0; "a great deal" = 9%). At the outset of the course, students expressed low interest in taking additional classes in the subject area—the mean response was 3.0 and almost two-thirds of the class (64%) selected "not at all" or "just a little." Baseline survey questions on "integration of learning" asked students to self-report their habits of connecting course topics they learn with other academic or life experiences. An integrative pedagogy and helping students developing these habits of mind and action are key features of the SENCER approach to science education. Similar to the earlier questions on academic skills, the mean responses to questions on integration and connecting knowledge to everyday life were fairly high (see Figure 4), with the most frequent responses being "somewhat" and "a lot." However, the proportion of students who answered "a great deal" to questions on integration was always less than 20%, revealing students' self-awareness that they could improve their skills in these areas. In summary, the baseline survey reveals that NYU students entered *Energy and Environment* course with strong confidence in their general academic skills but slightly lower levels of interest and integrative habits.

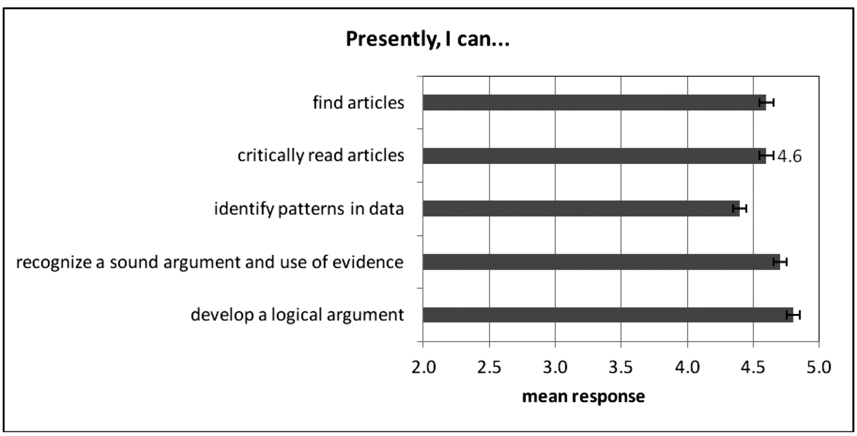


Figure 4. Student responses to SENCER-SALG baseline questions on skills (N = 465. Bars show the mean response ± one standard error. Some questions have been condensed to fit on the graph and complete wording of all questions is provided in the tables in the Appendix.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

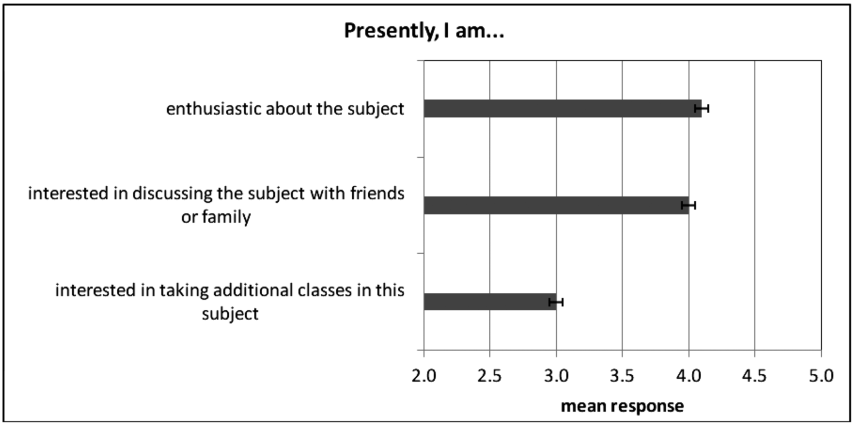


Figure 5. Student responses to SENCER-SALG baseline questions on attitudes (N = 465). Bars show the mean response ± one standard error. Some questions have been condensed to fit on the graph and complete wording of all questions is provided in the tables in the Appendix.

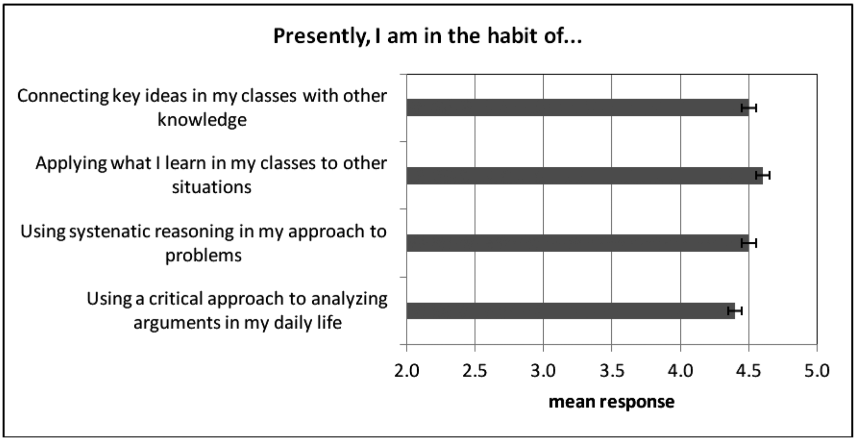


Figure 6. Student responses to SENCER-SALG baseline questions on integration (N = 465). Bars show the mean response ± one standard error. Some questions have been condensed to fit on the graph and complete wording of all questions is provided in the tables in the Appendix.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

What Does the SENCER-SALG Reveal About Student Learning?

The SENCER-SALG assessment instrument reveals detailed information on what students learned, what components of the course contributed to this learning, how their attitudes about science may have changed, how the course has affected their level of civic engagement, and how they perceived the course content to be integrated with their other studies and their life outside the classroom. This section of the chapter presents a selection of SENCER-SALG questions from the end-of-semester survey that are most closely connected to the course goals for *Energy and the Environment.* The data include survey responses from 431 students, which is 89% of the total course enrollment during four semesters.

Course Design and Student Learning

As shown in Figure 7 and Table A-III, students provided positive feedback about the overall instructional design of the class (mean = 4.4), with 82% responding that it provided "much help" or "great help." Students also affirmed their satisfaction about how the class included real world issues (mean = 4.4) and illustrated the interplay between science and civic issues (mean = 4.3); for both of these questions, the total proportion of students answering "much help" or "great help" was over 80%. The following two questions did not score quite as highly: learning how real science is done (mean = 4.0) and using scientific methods in the lab sessions (mean = 4.0). For these questions, just over 20% of students selected "moderate help" while the proportions for "much help" and "great help" were all close to 35%.

The two lower scores in this section of the survey identify areas where I could improve my course design and teaching. Several of the course lectures—particularly those dealing with the topic of climate change—did investigate "how real science is done." For example, the course examines how scientists drill deep into the ice (sometimes to a depth of over two miles) in Antarctica and Greenland and analyze the extracted ice cores to reconstruct the atmospheric composition and global climate of the Earth's distant past, extending back more than 800,000 years in some locations. We also discussed the pioneering work of Charles David Keeling, who collected atmospheric CO_2 measurements at the Mauna Loa observatory in Hawaii for more than 40 years and was able to demonstrate, for the first time, the annual variations in CO_2 levels due to photosynthesis and the inexorable rise of global CO_2 from the global consumption of fossil fuels (*43*). However, when I re-examined the syllabus in light of these results I realized that some other sections of the course do not have a strong focus on "real science," so students may have lost sight of the technical and social processes that generate scientific knowledge. Student feedback also indicates that the laboratory activities could be re-examined in order to provide a more meaningful experience of scientific inquiry. The experiments in *Energy and the Environment* are relatively simple given the limited time of the laboratory sessions (1 hour 40 minutes). However, there are several places within the laboratory curriculum where step-by-step procedures could be replaced or supplemented

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

by more open-ended investigations that better reflect the process of scientific investigation and foster students' abilities to design and interpret experiments.

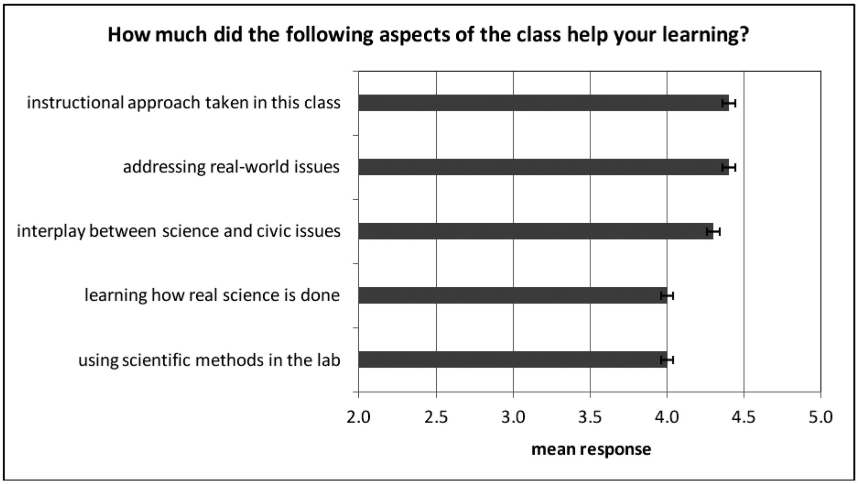


Figure 7. Student responses to SENCER-SALG questions on overall class design (N = 431). Bars show the mean response ± one standard error.

Gains in Understanding

The SENCER-SALG survey asks students to rate their "gains in understanding" on a Likert scale that ranges from "no gains" (score = 1) to "great gain" (score = 5). A summary of student responses to these questions are shown in Figures 8 and 9, with more detailed information presented in Table A-IV. Students reported only moderate gains in understanding "how scientists ask questions" (mean = 3.5) and "how scientific research is carried out" (mean = 3.7). The proportion of students who reported a "great gain" in their understanding of either topic was close to 20%, with most of the responses in the categories of "moderate gain" or "good gain." Students reported more positive gains in their understanding of scientific stories reported in the media (mean = 4.2), with almost three-quarters of them selecting "good gain" or "great gain." Throughout the semester I regularly used current articles from *The New York Times* and I encouraged students to contribute print articles, online news stories, or videos about course topics. Since the students in my courses are not planning to be science majors, the news media and online blogs will provide the primary (and possibly only) source of scientific information for the remainder of their lives. Developing an ability to critically evaluate these reports—or just pay attention to them in the first place—is an essential component of scientific literacy. The course was also successful in illustrating the connections between science and civic issues (mean = 4.2), with 47% of students reporting a "great gain" and 32% indicating a "good gain." The importance of his connection is a core component of SENCER's mission, so it was gratifying to see such a positive response on the SENCER-SALG survey.

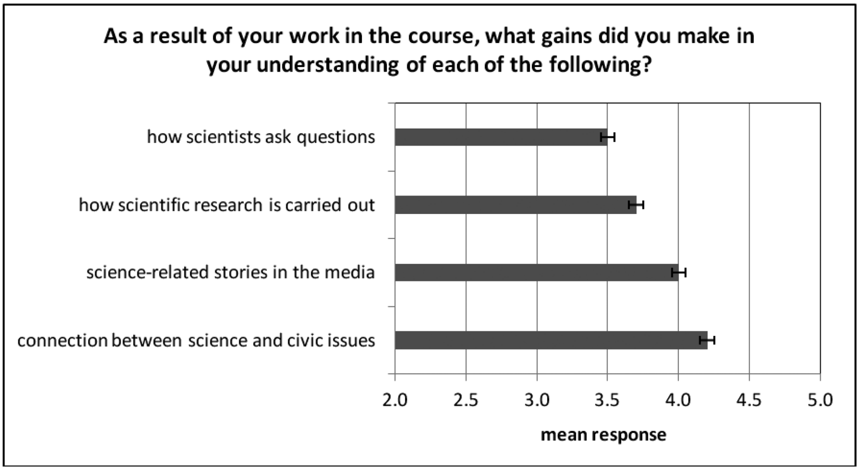


Figure 8. Student responses to SENCER-SALG questions on gains in understanding (Part 1) (N = 431). Bars show the mean response ± one standard error. Some questions have been condensed to fit on the graph and complete wording of all questions is provided in the tables in the Appendix.

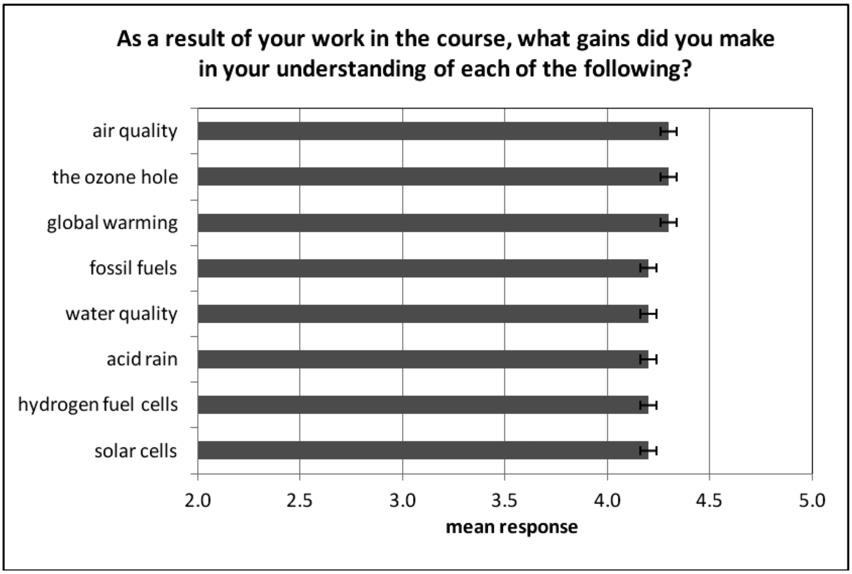


Figure 9. Student responses to SENCER-SALG questions on gains in understanding (Part 2) (N = 431). Bars show the mean response ± one standard error.

The baseline SENCER-SALG survey asked students to rate their understanding of scientific topics at the beginning of the semester (see Figure 3 and Table A-I). As a follow-up, the end-of-semester survey revisited these same topics and asked students to evaluate their gains in understanding as a result of the course. The results for these questions are presented in Figure 9 and Table A-IV. The learning gains reported by students for all topics were very high—the mean scores are either 4.2 or 4.3, and the proportion of students choosing "great gain" ranges from 46% to 53%. Based on this survey feedback, Energy and Environment was a successful course in helping students understand the scientific basis of the major environmental topics in the syllabus.

Development of Skills

In addition to increasing content knowledge, any non-majors science course should also promote the development of important skills such as evaluating scientific evidence, extracting the salient points from an article or website, and interpreting graphical representation of data. The development of skills (e.g., problems solving, quantitative reasoning, critical evaluation, etc.) is explicitly identified in the learning goals for *Energy and the Environment* (see Table I). Figure 10 summarizes students' self-assessment of their learning gains for a range of skills identified in the SENCER-SALG survey (see table A-V for further details). The mean scores on the Likert scale for these responses range from a low of 3.6 (searching for scientific evidence) to a high of 3.9 (evaluating scientific evidence in the media); the higher score for the latter question correlates closely with students' self-assessment of their media comprehension in the previous section. In general, we can see that all of the skill-based questions obtained a lower mean response score than the understanding-based questions reported in Figure 9 and Table A-IV. One interpretation is that *Energy and Environment* provided students with a strong foundation in scientific knowledge but was not as successful at developing their skills at evaluating scientific and quantitative evidence. Skills are "habits of mind" that often take a long time to develop, so a semester-long course may not be sufficient for students to achieve major learning gains. Another interpretation (which draws upon earlier discussions of validity), is that students are better at self-assessing more tangible learning gains like content knowledge but are not as adept at recognizing higher-order cognitive skills. Most students consider learning to be the acquisition of knowledge and under-value the development of skills, so they are more likely to self-report higher gains in content understanding rather than skills.

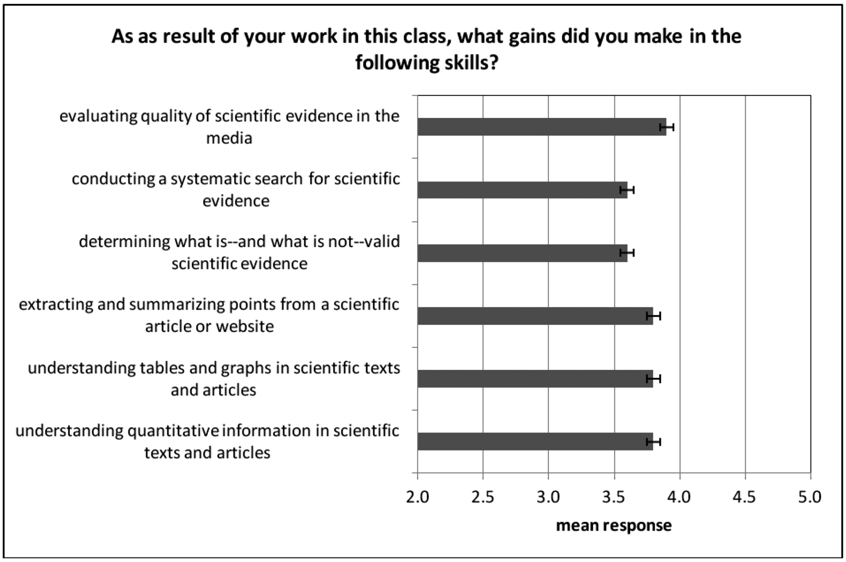


Figure 10. Student responses to SENCER-SALG questions on development of skills (N = 431). Bars show the mean response ± one standard error. Some questions have been condensed to fit on the graph and complete wording of all questions is provided in the tables in the Appendix.

Student Attitudes

Students' attitudes about science will affect their engagement with the course material, their willingness to learn, and the retention of course concepts after the end of the semester. The SENCER-SALG baseline survey revealed that students entered *Energy and Environment* with a fairly high level of enthusiasm for the topic, but with little interest in taking additional classes. A summary of student attitudes at the end of the semester is shown in Figure 11, with more details given in Table A-VI. Students indicated a moderate gain in their interest in science (mean = 3.4), with half of the students selecting "good gain" or "great gain." They expressed a slightly higher gain in their interest in civic issues such as air pollution, climate change, energy policy, etc. The mean score for this question is 3.8 and two-thirds of the students responded with "good gain" or "great gain." What is very obvious from the survey results is that students are *not* interested in taking additional science courses (mean = 2.8), majoring in a science-related field (mean = 2.3) or exploring career opportunities in science, which includes teaching science (mean = 2.3). The most frequent response for all these questions was "not at all," with especially strong opinions about their disinterest in a science major or a scientific career. Students showed greater interest in connecting environmental issues to their future studies outside of science in economics, law, literature, etc. The mean response to this question was 3.3 and—unlike most other questions—the distribution of responses was close to bimodal; a combined 48%

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

of students selected "good gain" or "great gain," while a total of 30% selected "no gains" or "a little gain."

The low level of student interest in continuing their study of science, either academically or as a career, is not unique to *Energy and the Environment*. In their extensive evaluation of the SENCER project (*10*), which examined over 10,000 student participants in the online SENCER-SALG survey, Weston, Seymour and Thiry report almost identical numerical responses to these questions, with mean scores of 2.69, 2.22, and 2.24 for questions asking students about their interest in taking additional science courses, majoring in a science-related field, and exploring career opportunities in science. These item responses were essentially unchanged from the baseline survey data obtained at the beginning of the semester. In summary: "Very small or statistically insignificant gains were found for most "advanced" science interest items such as interest in changing majors to a science related field, joining a science club, becoming a scientists or entering graduate school in science" ((*10*)*, p. 37*).

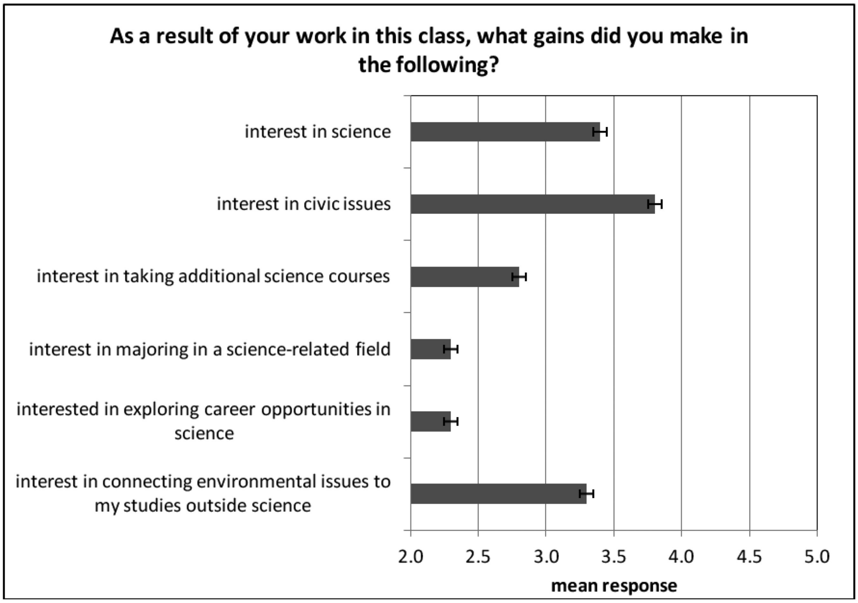


Figure 11. Student responses to SENCER-SALG questions on attitudes (N = 431). Bars show the mean response ± one standard error.

Should we be discouraged about what the SENCER-SALG survey is telling us about students' lack of interest in future scientific pursuits? Personally, I don't think so. The content and pedagogy of *Energy and the Environment* is designed for students who have expressed no interest in majoring in science—converting them into science majors is not a goal of the course, nor is it expected to be a likely outcome. Instead, the course is designed to promote scientific understanding and civic engagement so students can apply their scientific knowledge and reasoning skills in policy discussions and personal decision making; this educational goal is sometimes called *civic scientific literacy* (*44*). I consider my course to be successful if students integrate civic scientific literacy into their future roles as teachers, lawyers, business leaders, parents, non-profit employees, voters, and members of a democratic society. That being said, there have been a handful of students over the years who have credited the course for their decision to change their NYU major to environmental studies or a natural science.

Integration of Learning and Civic Engagement

Since the SENCER pedagogy teaches science through the framework of complex, unsolved civic issues, one of the desirable outcomes of a SENCER-based course is to stimulate students' interest in civic issues and their participation in civic activities. In addition, we want students to connect what they learn in the course (both content and skills) to other components of their academic studies and to their life outside the classroom. To evaluate these goals, one section of the end-of-semester SENCER-SALG survey is devoted to questions on integration of learning and civic engagement. A summary of the survey results for this section is shown in Figure 12 and further details are provided in Table A-VII. Students showed moderate interest in discussing science-related issues and civic/political issues with friends or family—the mean score was = 3.6 for both questions, and the number of students reporting "good gain" or "great gain" was well over 50%. Their interest in reading science articles or websites not required for class was slightly lower (mean = 3.3), but the number of students who selected "good gain or great gain" was still over 50%. Students provided similar feedback for the next question on critically evaluating scientific findings reported in the media (mean = 3.4; "good gain" or "great gain" = 53%). The lowest response by far was observed for the question where students were asked about their interest in taking PUBLIC action (emphasis in the original question) related to scientific or civic issues—the examples provided in the question are "interacting with public officials, working with a student or community group, speaking at public meetings, writing a letter to the editor, etc." The mean response was only 2.9, with 20% of students selecting "no gain," 21% "a little gain," and 26% "moderate gain." The responses were higher for questions that asked students about their integration of knowledge, such as connecting what they know about science to other classes (mean = 3.5), and applying their knowledge of science to civic and/or social issues (mean = 3.4.). Students also gave a generally positive response to questions about their critical thinking skills, such as using scientific reasoning to solve problems (mean = 3.4) and critically analyzing data and arguments in their daily life (mean = 3.5).

Since the curriculum of *Energy and the Environment* is infused with civic engagement examples (see Table III), the low level of student interest in "public" civic action merits further analysis. Once again, it is valuable to compare the results from my course to the large–scale evaluation by Weston and co-workers (*10*). The mean response in their survey of over 10,000 students was 3.36 for discussing a science-related issue and 3.30 for discussing a civic or political issue, which are slightly lower but still close to students' responses for *Energy and the Environment*. The version of the SENCER-SALG used by Weston in the earlier stages of the SENCER project contained more questions on civic engagement, each one addressing a specific type of civic activity (e.g., writing a letter to the editor, talking with a public official about a civic issue, attending a meeting or rally, etc.). The mean responses to all these questions were very low, ranging between 2.45 and 2.71. Based on these survey data, Weston and colleagues concluded that "A small minority of students engage in many of the civic activities asked about in the survey" ((*10*), *p. 38*).

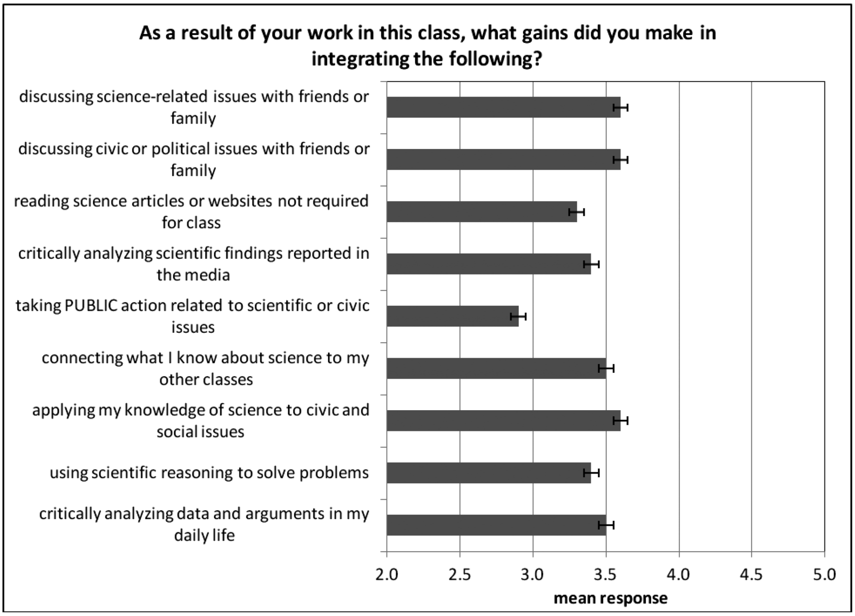


Figure 12. Student responses to SENCER-SALG questions on integration of learning and civic engagement (N = 431). Bars show the mean response ± one standard error.

Yet we need to acknowledge that expecting students to engage in a public act of civic engagement involves stretching far outside their comfort zone (at least for most students). While students may be willing to discuss their ideas with friends and family, which is typically a "safe space," it requires a large leap of confidence to take a public stand on a particular issue, which may invite personal exposure and criticism. In addition, the examples of public civic engagement provided in the SENCER-SALG survey (e.g., speaking at a public meeting) may strike students as being outdated and not connected to their daily lives. Millennial students now occupy a much different "public sphere" of social media such as Facebook and Twitter, where an online post about an environmental topic is a more relevant and accessible form of public civic engagement. Future versions of the SENCER-SALG survey would benefit from explicit inclusion of these social media as a forum for student civic engagement.

The low level of student interest in public acts of civic engagement expressed in the SENCER-SALG reminded me of the account provided by David Burns about his earliest experiences working with Professor Monica Devanas to develop a course on HIV/AIDS at Rutgers University in the 1990s (*1*). Created at a time when the AIDS epidemic seemed poised to become a potentially devastating threat to the health of college students, this course linked an academic pursuit with a public health objective—if students know more about HIV disease, will this knowledge prompt them to change their behavior to reduce the risk of HIV infection? Evaluation of the course showed mixed results (*45*). It did improve science learning but it generated only modest self-reported changes in the reduction of high-risk behaviors by students. Upon reflection, Burns concluded that the result should have been expected: Since the HIV/AIDS course did not include any specific content about behavior change, it was not reasonable to expect some "magical" change in student behavior. In other words, "you get results on the things you actively teach" *((1), p. 4)*.

I believe that a similar situation occurred within *Energy and the Environment*. I do not explicitly teach about public civic action in the course, so it is not surprising that students report low levels of interest. I intended the policy letter assignment on UV tanning beds (discussed in Section 2) to provide "practice" with the civic engagement activity of writing a well-crafted and persuasive letter to one's Congressional Representative. However, it is possible that the students in my class viewed this exercise as insufficiently authentic; they are smart enough to know that the letter was being written for a homework grade and would never actually be sent to Capitol Hill. While many SENCER-inspired courses provide students with a civic engagement experience through service-learning or participation in citizen science project, it is difficult to provide similar activities within a large lecture/lab course with restricted curricular flexibility. One innovative model to address this challenge is provided by the introductory chemistry course taught by Garon Smith at the University of Montana, which offers extra credit for students who participate in an out-of-class civic engagement activity such as attending or testifying at a public hearing (*46*).

Finally, our assessment of "civic engagement" is further complicated by multiple meanings of the term (*47*, *48*). Some proponents of civic education argue that some type of overt civic action is required, such as participation in community projects or involvement with the political process. But another perspective is provided by John Dewey, an American pragmatist and an influential philosopher of education. According to his biographer, Dewey believed that "Learning to think scientifically was important not just for future scientists but for all members of a democratic society…" *((49), p. 169)*. According to this view, both civic action and civic thinking fit comfortably within the umbrella term of "civic engagement" (*50*).

Analyzing Text Responses

Until this point I have mostly focused on the "common core" questions within the SENCER-SALG instrument, which are directly related to the central educational mission of SENCER. The use of a common framework for learning assessment enables us to implement a program-wide assessment of the SENCER project and provides useful insights into which student learning gains are shared across multiple SENCER-inspired courses and which are more course-specific.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Yet one of the most attractive features of the SENCER-SALG is its ability to be customized through the addition of specific questions, using either a Likert-scale or open-ended survey design. This flexibility allows the instructor to eliciting feedback from students on questions that he or she thinks are important, rather than being constrained by the *pro forma* language of traditional student course evaluations.

As their final reflection on the course, here is the last two-part question that students answer on my customized version of the SENCER-SALG:

> What is the ONE MOST IMPORTANT INSIGHT that you have gained from this class…
> …which is relevant to your studies at NYU?
> …which is relevant to your life outside the classroom?

To analyze the richness of student responses to this question, I took advantage of the coding functionality that is provided within the SENCER-SALG. Coding is a method commonly used for qualitative research and it involves assigning a descriptive word or short phrase that captures the essential meaning of a written passage (*51*). Assigning codes always requires some level of interpretation by the coder and is often guided by a particular research question or theoretical framework. My goal for coding was to gain a more detailed understanding of "relevance." It is often said that we should make learning "relevant" to students, but what do students themselves have to say about what they consider relevant? The analysis page for the online SENCER-SALG has an option called "add codes for text answers"; clicking on this link enables me to see each student's written response (anonymized using numerical identifiers) and provides a corresponding "coding box." After reading each response, I can enter one or more codes that capture the essence of each student's comments about the relevance of the course to his/her academic studies and life outside the classroom. After all the responses have been coded, the SENCER-SALG provides a numerical summary of which codes were used most often and by which students. This functionality enables a specific student's coded answer to be cross-referenced with his/her responses to any of the other questions within the SENCER-SALG.

A visual display of the most frequent codes to the question about "relevant to studies at NYU" is shown in Figure 13, which was created using the Wordle application (www.wordle.net). Each student response was assigned one or two codes (never more than two) and the frequency of each code word was calculated. A total of 363 written responses were coded and the cut-off threshold for inclusion was 2% of the coded responses (i.e., a code word had to be used at least 7-8 times). I did not include the "environment" or "environmental" as codes because this context of the course is assumed and the repeated use of these words would obscure the other comments. The "critical-thinking" code included student comments about critical and/or informed analysis of information, data, arguments, media reports, etc. The "study-habits" code was used when students mentioned some aspect of the course that enhanced their studying abilities, academic skills, preparation for exams, etc. The "science" code was used to identify student comments about the importance and/or relevance of science. From an analysis of the Wordle graphic, it is apparent that students considered "critical-thinking" and "study-habits" as being the two most important features of *Energy and the Environment* that were transferable to their other classes at NYU. Students also made frequent comments about the importance of science and sustainability for their studies. A particularly eloquent observation about the academic relevance of the course is provided below:

> As a journalism student, I am drawn more towards articles that deal with environmental issues as a result of this class. When reading *The New York Times* before taking this class, I would generally skip over a story on an environmental issue. After taking this course, I feel comfortable enough to read and understand the majority of material presented in the story. And, as a journalism student, I would like to conduct my own research and perhaps someday write about these topics on my own.

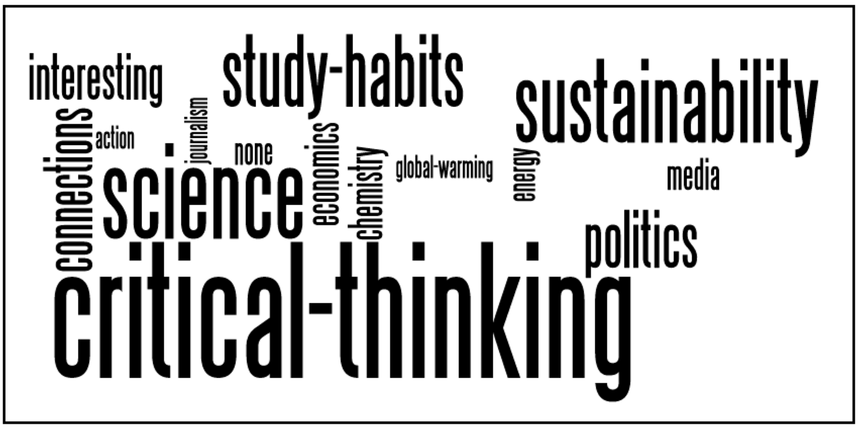


Figure 13. Display of codes for student comments about the relevance of the course to their studies at NYU.

Figure 14. Display of codes for student comments about the relevance of the course to their life outside the classroom.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

When students were asked to describe how the course was "relevant to their life outside the classroom, the most common theme by far was personal behavior. A visual display of the most frequent codes used for this question is shown in Figure 14. To create this graphic, 369 written responses were coded and the cut-off threshold for inclusion was 2% of the coded responses. Students provided a range of thoughtful answers about how their lifestyle impacts the environment and some specifically identified the actions they had taken (or planned to take) to lower their consumption of resources and reduce their carbon footprint. A representative sample of these comments is provided below.

> Environmental science is important in our everyday lives. It is something that we should always be aware of. These issues need to be addressed as they arise, not put on the back burner for the next generation to worry about. Small changes can have a big impact when it comes to the environment.
>
> We're all global citizens and sometimes we don't realize the aftermath of our actions. This class really made me reevaluate what I do and what can I do to help the environment. Everything just makes more sense now.
>
> The one most important insight that I have gained from this class is how to live a more earth-friendly lifestyle and be less wasteful. For instance, I've since switched from disposable plastic water bottles to an aluminum one.
>
> That action today or in the near future will be necessary to create a world that I would like to see myself and my children live in.
>
> That each of us has the power to effect change by changing our own habits and educating others on these environmental issues."
>
> The possibility of installing solar panels on my home in New Jersey, both with the aid of state tax incentives as well as PSE&G buy backs of excess energy. These insights took a bit of research outside of the class.
>
> I am more conscious of my carbon footprint, and will pay more attention to recycling and conserving energy in the future.
>
> Being more environmentally aware such as recycling, turning off the lights in classrooms and rooms that are not in use. Simply caring more about the world around me
>
> I have become more aware of my surroundings and know that I can make a difference, and have to start acting more environmentally responsible so that I can set an example for others to follow.

In terms of course topics, many students mentioned global warming as having an important impact on their lives (my coding of this question also included "climate change"). This awareness is important because climate change will be a defining global issue of the 21st century and we urgently need the engagement, creatively, and resourcefulness of today's college students to address its far-reaching consequences. A significant number of students also noted how the course had enabled them to become more effective critical thinkers in their analysis of debates and media stories about environmental issues.

By listening to students through their responses to the SENCER-SALG survey, I learned that *Energy and the Environment* has made an impact on students' level of civic engagement….but not in the way that was addressed by the core survey question. Instead of interacting with public officials, going to community meetings, or writing a letter to a newspaper editor, many of my students decided to make changes in their personal habits, such as giving up bottled water and filling an aluminum bottle with tap water, or investigating the feasibility of installing solar panels on the roof of the family home. Only time will tell if students stick with these plans or whether they will suffer the same fate as most New Year's resolutions. Nevertheless, encouraging students to connect their learning in the classroom to a reflective self-examination of personal responsibilities is a laudable civic goal of higher education.

Conclusion

Using the SENCER-SALG as an assessment instrument for *Energy and the Environment* provides a wealth of insight into students' content knowledge, response to pedagogical strategies, skill development, attitudes, interest, and civic engagement. This type of nuanced, "thick description" of the learning environment within my classroom is simply not possible by relying on the standard repertoire of course assignments and mandated end-of-semester student course evaluations. The SENCER-SALG is not designed or intended to replace direct measurements of course achievement such as final exams, but student self-assessment data can be used alongside these requirements as a complementary evaluation of student learning.

What did the SENCER-SALG revealed about my students' learning in *Energy and the Environment.* According to the survey data, the course was successful at increasing students' understanding of the key topics such as ozone depletion, global warming, etc. Students were enthusiastic about the instructional design of the course, especially the focus on "real-world issues" and the connections between science and civic issues. Students reported lower gains in skills such as evaluating the quality of scientific evidence and understanding scientific information that s presented in the form of tables, graphs, and numbers. One possible explanation for these survey results is that students often perceive learning as content-driven rather than skill-based. However, this student feedback suggests that I should be more explicit about developing skills within the course and explaining to students why they are important. At the end of the semester, students reported moderate interest gains for both science and civic issues, which is an encouraging trend in a required general education science course. One survey result that could potentially be disconcerting is the low level of student interest in taking additional science courses or pursing a career in science. However, as discussed above, the conversion of non-majors to science majors is not a goal of the course; instead, *Energy and the Environment* aims to develop students' "civic scientific literacy" in ways that will enhance their personal lives, future careers, and participation in a democratic society.

The most surprising and complex revelation of the SENCER-SALG survey was student feedback on how the course impacted their civic engagement. The initial results appeared disappointing—students expressed moderate interest in discussing scientific and civic issues with friends or family, but their commitment to traditional forms of public civic action was low. However, this result highlights the importance of considering the validity of an assessment instrument, as discussed in the earlier sections of the chapter. While writing a letter to the editor of a newspaper is a canonical form of civic engagement for those of us who serve as course instructors, the times have changed for our Millennial students. Their public sphere is now Facebook and Twitter and their civic engagement consists of posting, responding, and chatting online. This form of civic participation is not captured in the questions of the SENCER-SALG survey, so we are missing important insights into students' civic capacity in the early 21st century. Another interesting dimension of civic engagement was uncovered by the coding analysis of students' responses to the open-ended questions that I inserted at the end of the SENCER-SALG survey. When they were asked to share the "one most important insight" from the course that is relevant to their life outside the classroom, the overwhelming majority of students talked about changing some aspect of their personal behavior that has an impact on the environment. It was gratifying to see how students had processed what they had learned in the classroom and developed their own expression of "civic engagement" by recognizing their personal responsibility for our "common space"—both regionally and globally.

In conclusion, I encourage readers to visit the SALG website (*www.salgsite.org*) and consider what greater understanding about teaching and learning could be gained by using the SENCER-SALG in your own courses.

Acknowledgments

I wish to thank Stephen Carroll (Santa Clara University) and Melissa Ganus (Ganus Research and Advisory Services) for information and insights about the SENCER-SALG. I am also grateful to Daniel Holub (New York University) for obtaining the student enrollment data.

Appendix

Table A-I. Student Reponses to SENCER-SALG Baseline Questions on Understanding (N = 465)

Presently, I understand the following concepts that will be explored in this class[1]					
scientific concept	***not at all***	***just a little***	***somewhat***	***a lot***	***a great deal***
air quality	8 %	37 %	39 %	11 %	5 %
the ozone hole	16 %	39 %	33 %	7 %	4 %
global warming	4 %	22 %	49 %	17 %	6 %
fossil fuels	12 %	28 %	37 %	16 %	5 %
water quality	13 %	39 %	36 %	8 %	4 %
acid rain	23 %	36 %	29 %	6 %	3 %
hydrogen fuel cells	50 %	26 %	17 %	4 %	2 %
solar cells	43 %	31 %	16 %	6 %	2 %

[1] Students who answered "not applicable" (maximum of 2%) have been omitted from the table.

Table A-II. Student Reponses to SENCER-SALG Baseline Questions on Skills, Attitudes, and Integration (N = 465)

Presently, I can….[1]					
skill	***not at all***	***just a little***	***somewhat***	***a lot***	***a great deal***
Find articles relevant to a particular problem in professional journals or elsewhere	2 %	12 %	27 %	35 %	24 %
Critically read articles about issues raised in class	2 %	12 %	29 %	36 %	22 %
Identify patterns in data	3 %	15 %	36 %	32 %	14 %

Continued on next page.

Table A-II. (Continued). Student Reponses to SENCER-SALG Baseline Questions on Skills, Attitudes, and Integration (N = 465)

Presently, I can….[1]					
skill	***not at all***	***just a little***	***somewhat***	***a lot***	***a great deal***
Recognize a sound argument and appropriate use of evidence	2 %	9 %	27 %	41 %	21 %
Develop a logical argument	2 %	6 %	27 %	43 %	29 %
Presently, I am….[1]					
attitude	***not at all***	***just a little***	***somewhat***	***a lot***	***a great deal***
Enthusiastic about the subject	9 %	18 %	38 %	24 %	11 %
Interested in discussing the subject area with friends or family	11 %	22 %	33 %	24 %	9 %
Interested in taking or planning to take additional classes in this subject	37 %	27 %	25%	6 %	3 %
Presently, I am in the habit of…[1]					
integrative habit	***not at all***	***just a little***	***somewhat***	***a lot***	***a great deal***
Connecting key ideas I learn in my class with other knowledge	3 %	13 %	35 %	32 %	17 %
Applying what I learn in classes to other situations	2 %	9 %	34 %	37 %	17 %
Using systematic reasoning in my approach to problems	3 %	10 %	37 %	35 %	17 %
Using a critical approach to analyzing data and arguments in my daily life	3 %	15 %	33 %	33 %	16 %

[1] Students who answered "not applicable" (maximum of 2%) have been omitted from the table.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Table A-III. Student Reponses to SENCER-SALG Questions on Overall Class Design (N = 431)

How much did the following aspects of the class help your learning?[1]					
class characteristic	***no help***	***a little help***	***moderate help***	***much help***	***great help***
The instructional approach taken in this class	1 %	2 %	15 %	25 %	57 %
Addressing real-world issues	0 %	3 %	11 %	27 %	59 %
The interplay between science and civic issues	1 %	2 %	14 %	32 %	50 %
Learning how real science is done	0 %	5 %	23%	35 %	37 %
Using scientific methods in the lab sessions	1 %	6 %	21 %	37 %	35 %

[1] Students who answered "not applicable" (maximum of 1%) have been omitted from the table.

Table A-IV. Student Reponses to SENCER-SALG Questions on Gains in Understanding (N = 431)

As a result of your work in this class, what gains did you make in your understanding of each of the following?[1]					
general themes	***no gains***	***a little gain***	***moderate gain***	***good gain***	***great gain***
How scientists ask questions	3 %	12 %	31 %	35 %	19 %
How scientific research is carried out	2 %	12 %	27 %	39 %	21 %
The scientific issues and methods discussed in science-related stories in the media	1 %	4 %	23 %	34 %	38 %
The connections between science and civic issues at the local, national, and global level	1 %	2 %	18 %	32 %	47 %
scientific concepts	***no gains***	***a little gain***	***moderate gain***	***good gain***	***great gain***
air quality	0 %	3 %	12 %	39 %	48 %
the ozone hole	0 %	3 %	11 %	32 %	53 %

Continued on next page.

Table A-IV. (Continued). Student Reponses to SENCER-SALG Questions on Gains in Understanding (N = 431)

scientific concepts	*no gains*	*a little gain*	*moderate gain*	*good gain*	*great gain*
global warming	1 %	3 %	12 %	31 %	53 %
fossil fuels	1 %	5 %	13 %	30 %	51%
water quality	0 %	5 %	15 %	31 %	48 %
acid rain	0 %	4 %	15 %	31 %	48 %
hydrogen fuel cells	0 %	4 %	19 %	29 %	47 %
solar cells	0 %	3 %	16 %	31 %	48 %

[1] Students who answered “not applicable” (maximum of 1%) have been omitted from the table.

Table A-V. Student Reponses to SENCER-SALG Questions on Development of Skills (N = 431)

As a result of your work in this class, what gains did you make in the following skills[1]					
skill	*no gains*	*a little gain*	*moderate gain*	*good gain*	*great gain*
Evaluating the quality of scientific evidence in what I read and hear in the media	1 %	6 %	24 %	38 %	30 %
Conducting a systematic search for scientific evidence that is relevant to a specific question	3 %	8 %	33 %	33 %	21 %
Determining what is—and what is not—valid scientific evidence.	3 %	11 %	27 %	37 %	22 %
Extracting the important points from a scientific article or website and writing a coherent summary	1 %	10 %	21 %	37 %	30 %
Understanding tables and graphs commonly found in scientific texts and articles	2 %	10 %	22 %	37 %	29 %
Understanding quantitative information commonly found in scientific texts and articles	2 %	9 %	23 %	38 %	28 %

[1] Students who answered “not applicable” (maximum of 1%) have been omitted from the table.

Table A-VI. Student Reponses to SENCER-SALG Questions on Attitudes (N = 431)[1]

As a result of your work in this class, what gains did you make in the following?[1]					
attitude	***no gains***	***a little gain***	***moderate gain***	***good gain***	***great gain***
Interest in science	9 %	14 %	25 %	32 %	19 %
Interest in civic issues (e.g., air pollution, climate change, energy policy, etc.)	2 %	12 %	18 %	39 %	27 %
Interest in taking additional science courses after this one	24 %	18 %	22 %	17 %	1 %
Interest in majoring in a science-related field	45 %	15 %	16 %	10 %	12 %
Interest in exploring career opportunities in science (including teaching science)	45 %	16 %	14 %	12 %	12 %
Interest in connecting environmental topics to my future studies outside of science (e.g., economics, law, literature, etc.)	12 %	18 %	21 %	23 %	25 %

[1] Students who answered "not applicable" (maximum of 3%) have been omitted from the table.

Table A-VII. Student Reponses to SENCER-SALG Questions on Integration of Learning and Civic Engagement (N = 431)

As a result of your work in this class, what gains did you make in integrating the following?[1]					
integration	*no gains*	*a little gain*	*moderate gain*	*good gain*	*great gain*
Discussing science-related issues with friends or family	6 %	14 %	21 %	27 %	30 %
Discussing civic or political issues with friends or family	6 %	14 %	21 %	29 %	29 %
Reading scientific articles or websites not required for class	10 %	18 %	21 %	30 %	21 %
Critically analyzing scientific findings reported in the media	7 %	16 %	24 %	32 %	21 %

Continued on next page.

Table A-VII. (Continued). Student Reponses to SENCER-SALG Questions on Integration of Learning and Civic Engagement (N = 431)

As a result of your work in this class, what gains did you make in integrating the following?[1]					
integration	*no gains*	*a little gain*	*moderate gain*	*good gain*	*great gain*
Taking PUBLIC action related to scientific or civic issues (e.g., interacting with public officials, working with a student or community group, speaking at public meetings, writing a letter to the editor, etc.)	20 %	21 %	26 %	17 %	15 %
Connecting what I know about science to what I learn in my other classes	7 %	14 %	23 %	31 %	24 %
Applying my knowledge of science to civic and/or social issues	5 %	12 %	24 %	32 %	27 %
Using scientific reasoning to solve problems	9 %	14 %	28 %	27 %	20 %
Critically analyzing data and arguments in my daily life	7 %	15 %	24 %	29 %	23 %

[1] Students who answered "not applicable" (maximum of 1%) have been omitted from the table.

References

1. Burns, W. D. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 1−23.
2. Burns, W. D. *Sci. Educ. Civic Engage.: Int. J.* **2010** (Winter), 5–12.
3. Burns, W. D. *Sci. Educ. Civic Engage.: Int. J.* **2012** (Winter), 6–13.
4. Bretz, S. L. *J. Chem. Educ.* **2012**, *89*, 689–691.
5. Songer, N. B.; Ruiz-Primo, M. A. *J. Res. Sci. Teaching* **2012**, *49*, 683–690This is the introductory editorial to a special journal issue on assessment in science education.
6. Carroll, S. B. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 149−198.
7. Seymour, E.; Wiese, D.; Hunter, A.; Daffinrid, S. M. *Creating a Better Mousetrap: On-line Student Assessment of their Learning Gains*, 2000. www.aacu.org/resources/sciencehealth/documents/Mousetrap.pdf (accessed September 2012).

8. Carroll, S. B. 2012. Personal communication.
9. Weston, T.; Seymour, E.; Thiry, H.; Lottridge, S. M. *The Validity of the SENCER-SALG Online Survey for Course Revision and Student Outcomes*; ATLAS Evaluation Report; 2005; personal communication.
10. Weston, T.; Seymour, E.; Thiry, H. *Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project*, 2006. www.sencer.net/Assessment/pdfs/ExecSum_SENCER.pdf (accessed September 2012).
11. McGrath, R. E.; Mitchell, M.; Kim, B. H.; Lough, L. *Psychol. Bull.* **2010**, *136*, 450–470.
12. Cole, J. S.; Gonyea, R. M. *Res. Higher Educ.* **2010**, *51*, 305–319.
13. Kuh, G. D.; Carini, J. C.; Ouimer, R. M.; Gonyea, R. M.; Kennedy, J. *NSSE Technical and Norms Report*; Indiana University Center for Postsecondary Research and Planning, 2001. http://cpr.iub.edu/uploads/Norms!%20i-44.pdf (accessed September 2012).
14. Boud, D.; Falchikov, N. *Higher Educ.* **1989**, *18*, 529–549.
15. Falchikov, N.; Boud, D. *Rev. Educ. Res.* **1989**, *59*, 395–430.
16. Walser, T. M. *Innovative Higher Educ.* **2009**, *34*, 299–306.
17. Taras, M. *Teach. Higher Educ.* **2010**, *15*, 199–209.
18. Lew, M. D. N.; Alwis, W. A. M.; Schmidt, H. G. *Assess. Eval. Higher Educ.* **2010**, *35*, 135–156.
19. Heinze-Fry, J.-A. *J. Coll. Sci. Teach.* **1992**, *22*, 39–43.
20. Zoller, U.; Tsaparlis, G.; Fatsow, M.; Lubezky, A. *J. Coll. Sci. Teach.* **1997**, *27*, 99–101.
21. Zoller, U.; Fastow, M.; Lubezky, A.; Tsaparlis, G. *J. Chem. Educ.* **1999**, *76*, 112–113.
22. Tamir, P. *Int. J. Sci. Educ.* **1999**, *21*, 401–411.
23. Wiediger, S. D.; Hutchinson, J. S. *J. Chem. Educ.* **2002**, *79*, 120–124.
24. Dawson, M. E. *J. Coll. Sci. Teach.* **2005**, *34*, 32–33.
25. Ramirez, B. U. *Adv. Physiol. Educ.* **2010**, *34*, 134–136.
26. Tobias, S. *They're Not Dumb, They're Different: Stalking the Second Tier*; Research Corporation: Tuscon, AZ, 1994.
27. Seymour, E. *Talking About Leaving: Why Undergraduates Leave the Sciences*; Westview Press: Boulder, CO, 2000.
28. Geertz, C. In *The Interpretation of Cultures: Selected Essays*; Basic Books: New York, 1973; pp 3−30.
29. Ponterotto, J. G. *Qual. Rep.* **2006**, *11*, 538–549.
30. Renzi, V.; Jordan, T. *Peer Rev.* **2003**, *5*, 23–26.
31. Jordan, T. In *Future Directions in Higher Education*; Narum, J., Conover, K., Eds.; 2002; Vol. 112; pp 33−35.
32. Jordan, T. *Energy and the Environment*, 2002. http://serc.carleton.edu/sencer/energy_environment/index.html (accessed September 2012.
33. Middlecamp, C. H.; Jordan, T.; Shachter, A. M.; Lottridge, S.; Oates, K. K. *J. Chem. Educ.* **2006**, *83*, 1301–1307.
34. Middlecamp, C. H.; Phillips, M. F.; Bentley, A. K.; Baldwin, O. *J. Chem. Educ.* **2006**, *83*, 1308–1312.

35. Shachter, A. M. *Chemistry and the Environment*, 2001. http://serc.carleton.edu/sencer/chemistry_environment/index.html
36. Shachter, A. M.; Edgerly, J. S. *J. Chem. Educ.* **1999**, *76*, 1667–1670.
37. Masthay, M. B. In *Science Education and Civic Engagement: The SENCER Approach*; Sheardy, R. D., Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; pp 63−84.
38. Middlecamp, C. H. *Chemistry and Ethnicity: Uranium and American Indians*, 2004. http://serc.carleton.edu/sencer/uranium_american_indians/index.html (accessed September 2012).
39. Fisher, M. *The Chemistry of Daily Life: Malnutrition and Diabetes*, 2005. http://serc.carleton.edu/sencer/chemistry_daily_life/index.html.
40. Kim, B. S.; Szupnar, D. E. *Sci. Educ. Civic Engage.: Int. J.* **2010** (Summer), 35–40.
41. Middlecamp, C. H.; Keller, S. W.; Anderson, K. L.; Bentley, A. K.; Cann, M. C.; Ellis, J. P. *Chemistry in Context: Applying Chemistry to Society*, 7th ed.; McGraw-Hill: New York, 2012.
42. Jordan, T. In *Teaching Tips: Innovations in Undergraduate Science Instruction*; Druger, M., Siebert, E. D., Crow, L., Eds.; National Science Teachers Association Press: Washington, DC, 2004; pp 80−81.
43. Gillis, J. *The New York Times*, 2010. http://www.nytimes.com/2010/12/22/science/earth/22carbon.html?_r=1&pagewanted=all (accessed September 2012).
44. Miller, J. D. *Public Understanding Sci.* **1998**, *7*, 203–223.
45. Schneider, D.; Greenberg, M. R.; Devanas, M.; Sajja, A.; Goodhart, F.; Burns, W. D. *J. Am. Coll. Health* **1994**, *43*, 11–14.
46. Smith, G. *Liberal Educ.* **2004**, *90*, 40–45.
47. Jordan, T. In *Handbook of College Science Teaching*; Druger, M., Mintzes, J., Eds.; National Science Teachers Association Press: Washington, DC, 2006; pp 387−394.
48. Jacoby, B., Ed.; *Civic Engagement in Higher Education: Concepts and Practices*; Jossey-Bass: San Francisco, 2009.
49. Westbrook, R. B. *John Dewey and American Democracy*; Cornell University Press: Ithaca, 1991; pp 169.
50. Burns, W. D. *Liberal Educ.* **2002**, *88*, 20–27.
51. Saldana, J. *The Coding Manual for Qualitative Researchers*; Sage: London, 2009.

Chapter 14

The Importance of Interface: A Tale of Two Sites

Stephen B. Carroll*

Department of English, Santa Clara University, Santa Clara, California 95053
***E-mail: scarroll@scu.edu**

Two concurrent projects to expand the Student Assessment of their Learning Gains (SALG) course evaluation tool revealed that functional requirements of the website were less important than human factors in determining overall impact and success. The SALG is a valid, reliable, web-based tool developed through funding from the National Science Foundation which provides faculty with useful feedback about student learning in their courses. When the SALG Development Group (SDG) extended the SALG, which was originally designed for individual faculty, to serve departments and professional program evaluators, the SDG used the same site for both groups because the functional requirements of the groups were the same. The department site flourished while the evaluator site struggled somewhat. The SDG's analysis of those struggles and their causes uncovered vital principles of interface design that have little to do with functional requirements, but depend on audience needs and social context.

Growing a Successful Site

There are obvious advantages to adding new capabilities to a system that people already know and use. When Apple released the iPad in 2010, customers found it easy to work with because they had already used iPhones or Android smartphones so they knew how the operating system worked. Even though the iPad was a completely new kind of device, users could be productive with it right out of the box because they didn't have to learn a whole new interface from scratch.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

The iPad also killed an entire flock of birds with one featherweight stone. Carrying your iPad meant you no longer needed to carry your laptop, watch, camera, music player, address book, books, or even maps. It not only saved weight and hassle, it saved time, because everything was in one place. That it could perform so many essential tasks with so little added effort and that the interface was so familiar were key drivers of the iPad's rapid proliferation.

These thoughts were on the mind of the SALG Development Group (SDG) in 2006 as we started planning an expansion of the Student Assessment of their Learning Gains (SALG) website (*1*). Not that we were thinking about the iPad, which hadn't been invented yet, but assessment of student learning was becoming an increasingly important issue on college campuses across the country and we had an easy-to-use and popular assessment instrument that focused on learning outcomes and the pedagogies used to facilitate them. The first SALG website was available for almost ten years, from 1999 to 2008, and had about 1200 faculty users when we took it offline in summer 2008. The new site, which went live the day the old site was retired, doubled the user base within a year. Two years out, it had 3500 users and by summer 2011, it was up to 6500 users. By that time, it had been used to survey over 140,000 students. That steady, rapid growth showed that the SALG was clearly meeting faculty's assessment needs, but only one instructor at a time. The SALG was originally designed to be used by individual faculty to provide them with useful, specific feedback about their courses, so it was clearly fulfilling its mission, but the SDG thought that by adding a few new capabilities to the SALG, we could simultaneously serve the assessment needs not only of individual faculty, but also of departments and professional program evaluators. We would leverage the fact that users wouldn't have to learn a new system and save faculty time by making one instrument serve the needs of multiple constituencies.

Of course such a plan is not without dangers: history is replete with examples of popular and easy-to-use systems that when "upgraded" became too cumbersome, too slow, or too complicated, thereby losing their initially loyal client base. The most common causes of trouble when scaling up a system are insufficiently robust infrastructure to support increased demands on it and scope creep that leads to excessive complexity (*2*). The SDG therefore took proactive steps to ensure that neither of these things would sink our project. To accommodate a larger number of users, support the more complex processing demands, and keep the performance of the website sprightly, we beefed up the website's infrastructure so that it could easily handle 10,000-100,000 times more traffic than its maximum load to date. We knew from several studies that our users preferred simplicity and ease of use over advanced features and greater capabilities, so rather than add features to the site, we removed features, eliminating redundancies and seldom-used options. We also built a wizard that walks users through creating an instrument one decision at a time, obviating the need for complex user's guides or detailed instruction sets. We stubbornly resisted urges to expand the project by, for example, building a SALG for institutions. We were therefore confident that our expansion of the SALG site would go smoothly and that we would soon be serving departments and program evaluators as successfully as we were serving individual faculty.

We were half right. Building a new SALG site for departments went about as smoothly as could be expected. The department site went live in 2009 and gained users rapidly. By the end of 2009, 29 departments were using the site to assess their students' learning—and by extension their curricula's effectiveness. In 2010, another 104 departments began using it, and by September, 2011 another 122. However, when we tried to adapt that same department site for use by program evaluators, we learned some important lessons about audience and scaling up. Though we had anticipated the usual dangers, we had not adequately considered the degree to which both scale and audience affect the success of an interface. We had assumed that the interface which had worked so well for individual instructors and for departments would work just as well for professional evaluators. Not only did that turn out not to be the case, but the reasons why it worked so well in one case and not so well in the other reveal some important principles of interface design that are now guiding our redesign of both the department site and the upcoming site for program evaluators. We offer these principles here in the hope that they may similarly guide other teams as they scale up their projects.

The Student Assessment of their Learning Gains (SALG)

To understand the differences between the two phases of the project, we need to start at the beginning, with the origins and purposes of the SALG. The SALG was developed by Elaine Seymour and her research team in 1997 when she was serving as program evaluator for two NSF-sponsored chemistry consortia exploring modular curricula and pedagogies for undergraduate chemistry courses (ChemLinks and ModularCHEM) (*3*). As Seymour evaluated the pedagogical innovations at the heart of the two programs, she was struck by a paradox. Everyone agreed that the students in the experimental classes learned more than those in the control classes: the professors said so, the TAs said so, and the students themselves said so. Both subjective and objective evaluation of the students' work showed that the experimental group made greater gains in understanding, skills, learning retention and responsibility for learning than those in the control group. Yet students gave the professors in the experimental sections lower course evaluations than they gave those in the control classes. Further investigation revealed that the experimental courses pushed students out of their comfort zones and that because students were uncomfortable, they punished the faculty in the experimental sections by giving them lower course evaluation scores. The contradiction between the improved learning and the lower course evaluation scores revealed an inherent defect of traditional student course evaluations (SCEs): they don't measure learning (*4*). Faculty in the chemistry consortia criticized SCEs for (a) using students' satisfaction as the basic criterion instead of learning, (b) focusing on aspects of teachers' performance not directly related to learning outcomes, and (c) not evaluating the effectiveness of specific learning activities. Therefore, they observed, SCEs don't measure students' learning gains, nor do they garner useful formative feedback on course content or pedagogy (*5*, *6*).

The SALG was developed specifically to address these deficiencies of SCEs and to provide faculty—especially in STEM disciplines—with specific, useful feedback about their teaching. Thus, the SALG focuses entirely and exclusively on the degree to which a course helps students learn. It was designed around two primary principles that emerged from Seymour's research: (a) teaching effectiveness should be measured in terms of stated learning outcomes, and (b) students have something valuable to tell instructors about what they learned in a course and what helped them (or did not help them) make those learning gains. Following this basic philosophy, the SALG is divided into two main parts. The first section consists of four question sets which ask students to assess their progress toward course goals related to understanding, skills, affective changes and integration of their learning into their lives (habit formation). The first two question sets focus on content-goals, and correspond to Bloom's lower-level learning objectives. The latter two question sets index learning goals related to long-term retention of what was learned. The second section consists of six question sets related to the pedagogy used in the course. These questions ask students to assess the helpfulness of specific aspects of the course in facilitating the learning gains they evaluated in the first four question sets. The categories are overall course design, class activities, tests and graded assignments, class resources, meta-information about the course provided to students (e.g., explanations of why the course focused on the topics it did, advice on how to study specific concepts), and support provided to individual students. This two-part, ten-question structure, the two philosophical principles and the exclusive focus on student learning create the core identity of the SALG (*7*).

These principles and formal elements are vital because the content of the SALG is not fixed. Rather, the SALG's deep commitment to providing faculty with specific, useful, formative feedback about their courses requires that the SALG be adaptable to the specific goals and pedagogies of each course. Thus, while the categories of questions within the SALG are fixed, the individual questions are not. Every question in every section of the SALG can be edited or deleted by any user. Users are also free to add questions of their own choosing to any section, and they are equally free to add additional categories of questions and to fill those categories with questions of their own design. The SALG's design explicitly encourages this customization: some questions use a generic question header such as "The following concepts that have been explored in this class," and then list sub-questions: "Concept 1 (fill in)," "Concept 2 (fill in)," and so on (*8*). The only restrictions on user modifications are that there must be at least one question within each of the ten SALG question categories, and that the questions within those categories must use the original SALG answer scales (a gains-scale for the goals-related questions and a helpfulness scale for the pedagogy questions). These restrictions preserve the identity and integrity of the SALG (*9*). Enforcing this structure also facilitates collection and aggregation of data for research.

The adaptability of the SALG is intended not only to encourage users to adapt their instruments to the specifics of their own classes, but also to motivate pedagogical innovation leading to more effective teaching. One way it does this is by exposing instructors to a variety of teaching strategies. The SALG template includes questions related to group work, in-class discussions, visual and online resources, explanations of how to learn the materials, and other elements that are not part of traditional, lecture-based courses. Instructors see these questions every time they make a new instrument, and even if they erase these questions, that repeated exposure invites teachers to broaden their pedagogical repertoires. A 2005 study of 139 SALG users showed that most instructors using the SALG do make substantive changes to course design and instruction. Of the 39 SENCER instructors in that same survey, 34 reported making significant changes to their courses based on the feedback provided by the SALG (*10*). All but three of these instructors reported that the SALG responses were more useful to them than traditional course evaluations because they were more specific and focused on students' learning (*6*). The SALG was also designed to directly enhance students' learning by promoting increased metacognition about learning. Asking students what they learned and what helped them learn it requires them to reflect on how they learn and who they are as learners. As they become more metacognitive, students gain more control over their learning and become better learners. The SALG thus aims to work both sides of the teaching and learning street: it helps instructors become better teachers while simultaneously helping students become better learners.

A Short History of the SALG

A prototype SALG instrument was piloted as a pencil-and-paper survey in 1997 in three chemistry classes. Its demonstrated success there led to its use in 1998 in 18 chemistry classes or sections at 10 institutions connected to the chemistry consortia Seymour was evaluating. In 1999, the Wisconsin Center for Education Research's National Institute for Science Education and Exxon Mobile funded a project to build a website to deliver SALG surveys. This first SALG website was up from 1999 and 2008, and served approximately 1,200 instructors in more than 3,000 courses with over 65,000 students in STEM, social sciences and other disciplines.

An enhanced version of the SALG website was developed in 2003 to help meet SENCER's evaluation needs. The new site significantly extended the functionality of the original by enabling pre- and post- administrations of the SALG, allowing instructors to analyze student's initial levels of preparedness in addition to their learning gains.

A new SALG website for evaluators was developed at the same time, which allowed program evaluators to create templates that could be used by multiple instructors across multiple institutions to gather data on student learning. It also enabled evaluators to survey faculty (about their participation in the program, how extensively they modified their courses, etc.). Participating instructors started from templates (pre- and post-) created by the evaluator, but could add their own questions to the instruments they delivered to their classes. Instructors used the regular SALG site to deliver the surveys and the students logged into the student side of the site in the usual way. When students enrolled in SENCER classes logged into the SALG site, they were presented with an informed consent form and given the option of participating (or not) in the SENCER evaluation. Once the

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

surveys closed, evaluators received the data collected by the common questions on both the pre-and post-SALG templates, but could not access the data collected by questions added by individual instructors. Nor could evaluators see data from students who opted not to participate. Instructors had access to all data collected in their classes. Instructors could directly compare pre- and post- versions of the same items, providing them specific targets and guidance for pedagogical changes. By allowing SENCER evaluators to connect surveys of faculty to surveys of their students, the site facilitated a robust and detailed evaluation of the project. Among other things, that evaluation corroborated an earlier study showing that the SALG was a valid and reliable instrument for measuring students' learning gains (*5*, *6*). This evaluator site was used by SENCER evaluators from 2003-08 and more than 70 instructors participated in the evaluation. Those faculty members rated the site highly for utility and value, and reported making substantive changes to their course designs and pedagogies based on the feedback they received (*6*, *11*). Most significantly, this evaluation demonstrated the SALG's potential as an assessment tool for large scale educational research.

Based on that success, the SDG received funding from the National Science Foundation (NSF) in 2006 to replace aging infrastructure (servers, software, etc.), update the website and instrument and build new SALG websites for departments and program evaluators. The department site went live in 2009, and in 2010 two pilot programs began using the department site to test its suitability for program evaluators.

The Department Site

The success of the evaluator site built for SENCER demonstrated that SALG had value beyond its role as a formative assessment tool for individual faculty. The SDG saw that with relatively few modifications, the SALG could be used by departments and programs to gather data about students' progress toward department-level learning objectives. As a SALG site, the department site would focus exclusively on student learning and would be guided by the two core principles that guide all SALGs: (a) teaching effectiveness should be measured in terms of stated learning objectives and (b) students have something valuable to tell us about what they learned and what helped them learn it. After considerable discussion and a few extended experiments with alternatives, the SDG decided to continue to enforce the two-part, ten-question structure for the department site as well. As we planned the new site, the SDG added a new design principle: the new functionality should impose the least possible burden on faculty's time. We aimed to accomplish this primarily by embedding the departmental functions in individual faculty instruments. To achieve our objective, we realized that the added functions had to be seamlessly integrated into the old site and they had to be transparent and easy to use, so these became guiding design principles as well.

The SDG envisioned best practices beginning with department meetings to establish clear learning outcomes for each course. These outcomes would then be the basis for evaluating teaching effectiveness—as required by the first principle. Since accreditation agencies were already insisting that individual

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

faculty include these learning outcomes on syllabi and that departments develop alignment matrices showing how these outcomes fit together, the SDG assumed that this was happening in most departments already, making it easy for them to adopt the SALG to assess students' progress toward those objectives. Once the learning outcomes were agreed upon, the chair (or someone designated by the chair) would go to the SALG site for departments and create an account for the department. The specifications called for the site to be open, so anyone could sign in and create an account for any department at any university. (See Appendix 1: Department Site Registration and Appendix 2: Department Site Home.) The person who creates a SALG department automatically becomes the administrator for that department. The administrator then populates the SALG department by uploading a list of email addresses to the site. (See Appendix 3: Department Site Faculty List—Blank.) Anyone on that email list becomes a member of the department, and an individual faculty member can belong to an unlimited number of SALG departments. The administrator can then assign roles to people in the department. (See Appendix 4: Department Site Faculty List—Populated.) There are four possible roles, and the administrator can appoint as many or as few of each type as he or she desires, but everyone must have a role. Administrators have god-rights, allowing them to control any and all SALG department functions. Creators can create department instruments (explained below). Analyzers can analyze the results of department surveys. Faculty with the default role of None can use templates created by administrators (and creators) but have no other special privileges. Following the model of the SENCER evaluator site, a department instrument is simply a template with some questions "locked."

To create a department instrument, the administrator or creator begins with the standard SALG template with all the usual flexibility and restrictions in place. The administrator modifies one or more of the questions in the goals section (the first four questions) of the SALG to match the learning outcomes developed by the department. If the department requires specific pedagogical elements—for example, required texts—the administrator can modify the questions in the pedagogy section to reflect those requirements (*12*). Once the administrator (or creator) saves the instrument on the department site, it becomes available to all members of the department. A link bearing the SALG department's name appears on faculty members' home pages and provides access to all instruments for that department. (See Appendix 5: Department Membership.) Locked questions cannot be edited or deleted by the faculty member. (See Appendix 6: D Questions.) All other questions follow the same rules as questions on the SALG site for individual faculty: faculty can add, edit, move and delete as they choose so long as at least one question using the original answer scale remains in each of the ten question sets. Once the survey is closed, administrators and analysts (but not creators) have access to the data collected by the locked questions only. Instructors—even those with privileges set to None—can access all data collected by the survey they delivered to their class, including data collected by the locked questions. This differential routing system allows the department to collect data related to agreed-upon departmental learning outcomes yet facilitates pedagogical experimentation by preserving the privacy of the faculty, allowing them to try new strategies without fear that less than optimal results will become public

(*13*). Finally, the specifications for the department site called for more advanced analysis tools than those on the SALG for individual faculty. The SDG predicted that departments would want to look not only at results for individual classes, but that they would want to aggregate data by faculty member, course, term, year, and perhaps other variables (e.g., specific curricular outcomes).

As built, the department site matches the specifications described above with a couple of notable exceptions. First, interoperability between the regular SALG site and the department site was not always as seamless or transparent as we planned. Early on, moving instruments back and forth between the two sites was often problematic. This made it hard for department administrators to create department instruments based on instruments they had already created on the regular SALG site, and it sometimes made it more complicated than necessary for users to access department instruments. The vast majority of department users were unaffected by either problem, but those affected experienced some frustration until work-arounds were developed. Second, the analysis feature for the department site has not been completed as of the date of this writing. Department administrators and analysts can run standard analyses of individual instruments: they can view numbers of respondents, average scores, standard deviations, means and modes, and student responses to open-ended questions. They can aggregate instruments for a single faculty member and run crosstabs on that data. They can also download results of individual surveys as Excel spreadsheets, which can then be combined offline and aggregated using Excel or SPSS or some other statistical software package. However, the more robust analysis features called for in the initial specifications for the department site have yet to be built; this was due in part to turnover in the programming staff, and in part to a flaw in the design of the database that is now being corrected (*14*). In any case, the delay in providing the analysis package appears not to have significantly affected the adoption of the department site. There has been only one complaint to the help desk (it was about the missing analysis feature), but the aggrieved department opted to use the department SALG even without that feature. Even though the department site is just over three years old, it is already being used by over 300 departments at nearly 200 institutions. It has been even more successful than we had hoped it would be.

A reasonable next step after developing the department site would have been to build some kind of trans-departmental site: a site for schools, colleges or even small universities. Such a site might be organized according to a nested logic, whereby a school or college administrator would lock certain questions on a template that would then trickle down to all the departments within that school. The department administrators would then lock questions of their own before passing departmental templates down to their faculty. Faculty would then be able to add questions of their own and to delete or modify any questions that weren't locked. After the surveys were completed, instructors would get back all the data on their surveys, department administrators would get back the answers to the questions they locked and to the questions locked by the school, and administrators would get back the answers only to the questions they locked. Such a site would simply extend the logic used in building the department site, and the SDG has been planning to build such a site since 2006, when we first proposed the department and evaluator sites to the NSF. However, the SDG was wary of scope creep and of expanding too fast. We were worried in particular that such a site would be more complicated than either the department site or the evaluator site. We therefore decided not to tackle what we refer to internally as the institutional site until after we got the other two new sites up and running well.

The Evaluator Site

In retrospect, we might have gotten that decision backwards. The architecture and programming for the department site is relatively straightforward and robust; it has worked very well for its intended audience. Extending it one more step up the institutional ladder will probably not be difficult, given the similarities in the audience's needs. Adapting the department site to the needs of program evaluators, on the other hand, proved to more complicated than we anticipated. In developing the evaluator site, the SDG relied once again on the model used by the SENCER evaluators: we planned a site very similar to the department site with a few extra features. Our specifications called for the same capabilities that made the SENCER evaluator site successful: it should provide a means for evaluators to survey faculty and to link the results of that survey to surveys of those faculty members' students, and it should provide a means of delivering consent forms to both faculty and students. We thought both problems would be relatively easy to solve. Since the SALG doesn't differentiate between faculty and student email addresses, the same mechanisms used to survey students can be used for faculty. Creating links in the database associates a faculty member's answers to the data gathered from his or her students. This is not a simple piece of programming, but neither is it especially difficult, and since neither of the evaluators who volunteered to pilot the evaluator site needed to survey faculty, we could proceed without it. Similarly, neither of the evaluators we were working with needed students or faculty to sign consent forms, so again we could move ahead with the pilot as we worked on programming these features.

We also considered that program evaluators would need to work across multiple institutions, but since enrolling faculty in programs being evaluated would consist of uploading lists of email addresses, we didn't anticipate that this would need to work any differently than it did on the department site. We also thought that program evaluators might want an analysis package even more sophisticated than the one we were building for the department site. However, we knew from having two professional program evaluators—Seymour and Weston—on the SDG that analytical needs vary widely according to the goals of the program being evaluated. And since most program evaluators use independent statistical packages like SPSS to process their data, we theorized that while we weren't yet providing a complete solution, the absence of analytical tools wouldn't seriously inconvenience evaluators who were used to providing those tools. We therefore decided that we would run a pilot without any analytical tools. Based on the pilot, we would assess what kinds of analytical tools were needed and whether or not we could provide them. We preferred the option of building the appropriate analytical capacities into our system, but if that proved overly ambitious, we believed that there would still be value in offering the SALG as a way of collecting data while leaving the processing of that data to some external system.

After careful consideration and discussions extending over three years, we decided that while we would eventually need to add the features mentioned above to the evaluator site, in essence, the evaluator site would look and operate more or less the same way as the department site. Therefore, we would use the department site as it was to pilot the evaluator site. We recruited two large-scale projects for the pilot: URSSA (Undergraduate Research Student Self-Assessment) and GLISTEN (Great Lakes Innovative Stewardship through Education Network) (*15*). We already had working relationships with the Primary Investigators (PIs) of both projects, and both projects were interested in assessing student learning in ways that were very compatible with the SALG's philosophical underpinnings, so we anticipated a smooth and successful pilot.

URSSA

URSSA was our first test. Their philosophical approach was very compatible with the SDG's and their instrument—developed in 2009—was based on the SALG, so it seemed to fit easily into our model. Although the URSSA instrument was quite different from the SALG—for example, the URSSA has 30 question sets instead of 10, and nearly all of the questions are locked—most of the differences were easy to accommodate because the SALG site had been designed with just this kind of flexibility in mind. One difference, however, proved quite instructive. The URSSA team wanted to delete some core question sets from their instrument because those questions pertained to courses but not so much to undergraduate research experiences. They wanted to edit some of the wording in other core questions for the same reason: the language about courses in those questions didn't make sense in the new context (*16*). Because the SALG was originally designed to evaluate classroom learning, it didn't accommodate these other learning situations gracefully. On the other hand, some important educational experiences clearly don't revolve around classes, so we needed to give program evaluators more flexibility to modify and delete core questions than we had planned. In this particular case, we knew the URSSA PIs well and trusted them to stay true to the core principles that kept the resulting instrument consistent with the SALG philosophy, but this experience taught us not only that program evaluators need more freedom to modify their instruments than we had given departments, but also that maintaining the SALG philosophy and identity on the evaluator site was going to be more complicated than we thought.

The second set of issues raised by URSSA dealt with access: specifically, how people join a research project. On the department site, this process is controlled by the chair or a delegate. That person enters a list of email addresses into the site and the people with those email addresses become members of the department. The roster is presented in a simple, fixed table with columns for name, email address, privileges and number of (department) surveys completed. (See Appendix 5: Department Membership.) For a department, managing this list is not difficult because (a) every department has a definitive list of who is in the department, (b) most departments are small enough that any member's row can be quickly found and edited. The same was not true for URSSA. Whereas most departments have many fewer than 100 people, URSSA was collecting data for multiple research projects, some of which involved hundreds of faculty. In some cases, there wasn't a definitive list of participants at the beginning of the project, which meant that the roster wasn't entered in any particular order. Thus, finding and editing an entry for a specific participant became a difficult and time-consuming task. URSSA needed a way to search and sort the roster so that they could manage their participants effectively. We soon found that GLISTEN shared this need.

More importantly, the URSSA project wasn't a closed system with a defined group of participants. Rather, URSSA researchers wanted faculty running undergraduate research programs across the country to be able to use their instrument whenever it was appropriate. Hence, they had no way of knowing in advance who would want to use their instrument. Yet at the same time, they wanted to support (and analyze the data for) grant-funded research projects with defined groups of participants and specific reporting requirements. Having people send them lists of email addresses to enter into the system proved frustrating and inefficient on both sides and delays in entering the lists often precluded clients from using the URSSA instrument when they needed it. Moreover, as individual faculty often joined and/or left a particular project from year to year, maintaining control of the list became increasingly unwieldy. Thus, URSSA needed both a self-sign up mechanism that would allow individuals to add themselves to the roster and a notification system that would inform URSSA personnel of these additions so that URSSA administrators could include or exclude people from datasets as appropriate.

Our experience with URSSA was valuable because it revealed some of the outer limits of the SALG's capabilities. For example, it demonstrated pointedly that despite our ambitions for SALG to be a universal survey instrument for any program evaluators assessing student learning, the standard SALG works best for evaluating course-based learning. Our experience with URSSA reminded us that many kinds of educational experiences don't involve formal courses of the kind the SALG is designed to assess. URSSA's issues with access and the enrollment system similarly demonstrated that our thinking about how people might want to use our system had become too narrow. Finally, the depth of the changes that URSSA wanted to make to both the instrument and the website showed that we still had not adequately resolved the tensions between flexibility and identity. To give program evaluators the flexibility they needed to assess pedagogical innovations, we would need to figure out a way to lift or relax some of the restrictions without compromising the integrity and identity of the SALG. Because URSSA's goals and audience went beyond what the SALG was originally designed to evaluate, this pilot helped us understand how to push those outer limits.

GLISTEN

Whereas URSSA pressed the SALG's outer limits, the GLISTEN project was exactly the kind of project the SDG was aiming at when we developed the evaluator site. Launched in 2010, and funded by the Learn and Serve America program of the Corporation for National and Community Service, GLISTEN fosters development of undergraduate coursework that incorporates environmental service-learning components focused on restoration and stewardship of the Great Lakes ecosystem. Even though GLISTEN includes faculty from over 20 institutions in eight states, the SDG believed that creating a "GLISTEN Department" on the SALG site to deliver specially-designed templates focusing on the impact of the environmental service-learning components would make evaluation of the project's effects on student learning relatively straightforward. In theory, evaluation of the GLISTEN project using the departmental function of the SALG should have been a relatively easy task because this was just the type of project the site was designed for: it was class-based, no custom language or programming were required, and the GLISTEN instrument tested neither the philosophy nor the identity of the SALG.

In practice, GLISTEN presented major challenges to the SALG site's inner limits which, in turn, created ongoing difficulties for GLISTEN Project Director Glenn Odenbrett, of the National Center for Science and Civic Engagement. Expressed here from Glenn's perspective, these difficulties primarily involved effective management of faculty's access to the department and instrument template as well as verification of instrument status (creation, modification, administration, analysis) in real time.

- **Establishing and verifying departmental affiliation of faculty and instruments**. As the GLISTEN Department Administrator, I provide access to the GLISTEN Department for faculty affiliated with the project by adding their email addresses to the faculty list. The next time a faculty member on this list logs into the SALG site using *this email address* (there have been numerous problems with faculty using alternate email addresses), they are automatically affiliated with GLISTEN. Once the faculty member is correctly affiliated, the site will tell me how many instruments that person has created. However, the site won't tell me the status of those instruments, an issue I'll return to below. Nor will the site tell me whether these instruments are correctly associated with GLISTEN. Faculty can belong to more than one SALG department: e.g., a discipline-specific one at their own institutions as well as the multi-institutional GLISTEN department. They can also create instruments for courses not affiliated with the GLISTEN project. Under normal circumstances, none of these instruments would appear on the list of GLISTEN instruments I see, but—as a number of faculty have proved—it is possible for faculty members to open a GLISTEN template and use it for the wrong department or for a course not associated with GLISTEN. These instruments will appear on the list as GLISTEN instruments and will be included in the dataset, even though they shouldn't. Currently, the only way for me to determine whether these instruments are GLISTEN-affiliated is to examine them individually, a very time-consuming process.

- **Identifying and preserving the SALG template specific to the GLISTEN department.** There is a fairly well-developed wizard on the SALG site that offers users detailed guidance on how to create an instrument using one of the templates developed by the SDG. The SDG was able to adapt this wizard for use by GLISTEN faculty, but doing so caused an unexpected problem: when GLISTEN faculty accessed the templates for the GLISTEN SALG, they were presented with two choices. At the top of their screen, the names of the GLISTEN templates appeared in big green letters, indicating that they were links for accessing the templates. Contrary to all these visual indicators, faculty were not supposed to click these links because they accessed the templates directly. Instead, faculty were supposed to click a much smaller link near the bottom of the screen that would allow them to "Reuse/adapt" the templates. Clicking on the links to the templates posed two dangers. Early on, it was possible for faculty to alter the GLISTEN SALG templates, thereby creating a huge number of new GLISTEN department instruments. That glitch was soon fixed, but I quickly learned that when faculty clicked on the templates, the software wasn't creating instruments out of them. Instead, faculty were working with templates, which cannot be delivered to students as surveys. Even more frustrating, the faculty had no way to know this; the wizard walked them through the process just as it would for an instrument, but at the end of that process, there was no instrument. Thus, it quickly became apparent that special instructions had to be developed and disseminated independently of the SALG site to ensure that GLISTEN-affiliated faculty made the right choices and did not access the GLISTEN departmental templates. Despite these carefully-constructed instruction sets, conference calls have been necessary to ensure that users understand and follow the instructions.

- **Sorting users and instruments by faculty member, institution, discipline, geography, and type (Baseline vs. Full SALG)**. On the current SALG site, I have access to three master lists that I can see but not sort: faculty registered in the site (see Appendix 7: GLISTEN Faculty List), instruments created (see Appendix 8: GLISTEN Department Instruments), and instruments administered with analyzable results (see Appendix 9: GLISTEN Faculty Instruments). While it is somewhat inconvenient not to be able to sort the faculty and administered instruments lists, it is absolutely maddening when it comes to the list of instruments themselves. The list of faculty is slightly less than 100 names long, and I can at least search the list using my browser's search command. The list of administered instruments presently shows 185 instruments, and while the list is missing certain important information like the instrument number and the faculty member's name, it does include the status of the instrument (completed or in progress), the open and close date of the instrument, the semester, the name and description of the course, and the number of responses to the survey. The list of instruments created, on the other hand, is over 300 items long and fewer than 15% of them display any information at all. The list is filled with "test" instruments that faculty created as they learned to use the site and which no longer have any value, but clutter the list and make it virtually unusable. Unless faculty themselves delete these instruments, they remain in what has become an enormous list of instruments that are added chronologically and cannot be sorted at all.

Although the site keeps track of a variety of sort-relevant categories (e.g., institutional affiliation, semester of administration), there is no way on the site for me to electronically sort users or their instruments into disciplinary, geographic, or other cross-institutional groupings for detailed analysis. All such sorting must be conducted manually; instruments can then be selected for aggregate analysis based on these manual sorts, which become more time-consuming as the number of participating faculty and instruments increases. In the case of GLISTEN, which is organized into geographic clusters of institutions spread over eight states, identifying key factors that might explain differences in student learning has been virtually impossible due to the amount of manual sorting required.

- **Tracking instrument status: creation, development, and administration**. To be maximally effective as a SALG department administrator, I need to be able to quickly verify the status of instruments created and administered by GLISTEN faculty. Currently, until an instrument has actually been administered and the survey is closed, there is no way for me (or any department administrator) to know whether an instrument is still being developed, complete but not yet scheduled for administration, or scheduled to be administered. One consequence of this "instrument status blindness" is that I am unable to detect or troubleshoot problems for my faculty. For example, if a faculty member sets up a template instead of an instrument or misses a step crucial to the administration process, I will never know about it. If the faculty member fails to set the administration date parameters correctly, I will never know whether the instrument has been administered at all. If the faculty member doesn't grant students access to an instrument appropriately, the site may open and close an instrument without analyzable results having been generated, and I won't see this until the survey closes with zero responses. My attempts at trouble-shooting have therefore been limited mostly to the post-administration period, when it may be too late, once a semester is over, to help faculty correct settings that will encourage, enable, and control student access.

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

GLISTEN is just the kind of project the SDG designed the evaluator site for: GLISTEN is class-based but multi-institutional, it uses an instrument that fits comfortably within the SALG philosophy and doesn't need to override any of the normal restrictions, and it has a clearly defined membership. Because GLISTEN fit the SDG's vision of our site so well, the difficulties Glenn relates above highlighted the inner limits of our site. In essence, we had presumed that GLISTEN was—or could be treated like—a kind of super-department. Although we recognized that Glenn might need to sort data gathered by GLISTEN instruments according to categories like institution or state that normal departments aren't concerned with, we still thought that GLISTEN would in most other ways function as a department would. The most valuable lesson we learned from this part of the pilot was that this is definitively not so.

One of the key differences is scale: departments usually comprise a few dozen people—a really big department may have a hundred or more—but research projects can involve thousands or even tens of thousands of faculty. An order of magnitude (or two) difference in size means that program evaluators can't manage associated faculty with a simple list. They need ways to search and sort the lists so they can find information quickly and easily. Although we had proactively beefed up the physical infrastructure of the site as we planned our expansion, we had not paid sufficient attention to the limits of our system for handling the faculty roster. Radically increasing the size of the roster required a much more powerful and flexible system for managing it.

Other key differences between departments and research projects concern how those communities are constructed and maintained. Departments are physical communities with systems for communicating with and controlling its members that are so strong and so pervasive, they are generally only visible when they are malfunctioning or missing. Departments, for example, have multiple means of communication, including not just mail, phone and email, but department meetings, newsletters, and physical distribution of documents through department mailboxes. Even more important, department members work in close physical proximity, so there are numerous opportunities for quick questions, conversations and even gossip. This wealth of communications options allows department administrators to communicate information to faculty in a variety of ways according to the message, the context, the audience, etc. Research project administrators enjoy far fewer options for communicating with their faculty participants, and because the community over which they preside is virtual instead of physical, the most vital, most nuanced and most effective means of communication—those that depend on physical presence—are unavailable to them in most cases (*17*). Moreover, whereas department administrators can avail themselves of both carrots and sticks to influence their faculty's compliance with learning assessment policies or initiatives, few research project administrators can offer more than the most token of carrots. Finally, most faculty put a relatively high value on their membership in their departmental community; over time that membership gets imbricated in their professional and personal identities. Conversely, most faculty regard research projects in which they are merely one among hundreds or thousands of participants as far less vital, less consequential to their career and identity. As a result, department administrators can generally expect their faculty to read and respond to their communications promptly and appropriately and to comply with departmental directives. Both internalized and social pressures lend departmental communications a kind of urgency that is largely absent for participants in large research projects. Thus, while department administrators can rely on means external to the SALG site to communicate with and manage their faculty—and therefore place far fewer demands on the site itself, program evaluators need the site to provide internal tools that allow them to understand, monitor and guide what their faculty participants are doing and to intervene when necessary.

This was perhaps the most important thing GLISTEN taught us about the internal limits of the SALG: the extent to which the SALG site's success depends on communication and control systems that are built into the structures of academic departments. The first SALG expansion, from individuals to departments, went smoothly because departmental communication and control systems were able to compensate for their absence in the site itself. Because those systems are part of the water that we academic fish swim in, we didn't even notice their presence, let alone their importance. Those systems and structures only became visible through their absence. The fact that GLISTEN is not an academic department and is therefore missing these communication and control systems revealed just how profoundly those systems had shaped and supported the department site.

Outcomes: Upcoming Changes to the Evaluator Site

The SDG greatly appreciates the patience and good humor of the leaders of the URSSA and GLISTEN projects during the pilot of the evaluator site. The problems and deficiencies they exposed as they exercised the site taught the SDG valuable lessons about the outer and inner limits of the SALG. They provided specific suggestions about where our programming needs to be fixed, and their experiences showed us where and how our thinking had led us to "solutions" that didn't match their needs. By guiding us to a more accurate understanding of their needs, and by exposing us to diverse user behaviors that didn't conform to our expectations, they not only helped us understand how to fix known problems, they taught us important principles of interface design that will allow us to avoid similar types of problems as we continue to develop the site.

A new version of the SALG site is scheduled to be released in late 2012, and many of the changes focus on remedying weaknesses exposed by URSSA and GLISTEN. First, per our experiences with URSSA, the new site will allow faculty to sign themselves up as participants in a research project, notify administrators of these enrollments, and give them the option of including or excluding those faculty from the project. Not only will this capability meet URSSA's needs, it should reduce administrative loads on evaluators of large projects. The SDG will also add the ability to create custom portals for large projects like URSSA and GLISTEN. These portals will allow program evaluators to create customized websites under the SALG umbrella with language and processes tailored to the specific needs of the project. Building such portals offers the SDG the opportunity to finesse the philosophical identity problem: it allows us to keep the restrictions that guarantee the integrity of the SALG in place even on the evaluator site and to allow approved evaluators to override those restrictions in a portal site after they have negotiated with the SDG.

Further changes to the site will accommodate the needs of projects like GLISTEN. The SDG has already altered the site programming to prevent users from making modifications to department templates, and the new version of the site will have clearer directions to guide users who want to reuse a department instrument. The most important change, however, will be the introduction of a dashboard for project administrators that will allow them monitor the status of all instruments associated with their project. That dashboard will be searchable and sortable by any and all of the categories associated with those instruments: instrument number, instrument status, faculty name, class name and description, academic term, open and close dates, etc. A similar dashboard will allow administrators to monitor and control the status of faculty associated with the project. Again, the table will be searchable and sortable in much the same way that a user can click on a column heading in Excel or Outlook to sort and/or find data within that column. These two dashboards will allow program evaluators to (a) establish and verify affiliations of faculty and instruments, (b) sort users and instruments by faculty member, institution, type, etc. and (c) track instrument status through creation, development and administration. These changes should make the SALG much more useful to program evaluators.

Analysis: Lessons Learned

The first conclusion we want to draw is that the department site worked well in its native application. Even without the planned analysis tools, nearly two hundred departments have found it valuable in helping them understand their students' learning gains. The SDG attributes this success to our familiarity with the audience for the department site. In hindsight, we should also credit the invisible hand of departmental communications and control infrastructures that compensated so well for some shortcomings of the site that we didn't even realize they were shortcomings until we expanded the site beyond the reach of that infrastructure. Strangely, our inability to see this infrastructure further testifies to our deep understanding of this audience: because it is so pervasive in our lives, our site design assumed that it would continue to operate even in environments where it was clearly absent. All members of the SDG have been members of academic departments for many years, so we understood their needs and how they operate. We understood this audience so well that we even predicted points of failure and built features into the department site to accommodate those likely sticking points. For example, we knew that most departments have one or two faculty who comply with department policies only reluctantly, and we suspected that there would be faculty in many departments who weren't really that interested in assessment or in understanding their students' learning. We therefore built a wizard especially for them that takes the shortest possible path through the SALG site. Instead of offering these users opportunities to customize the departmental SALG for their classes, this wizard invisibly defaults to the most common choices and requires the user only to enter the name and description of the class, choose the open and close dates for the survey and notify the students. (If the user becomes curious or wants to make changes later, he or she can reopen the instrument and gain full access to the usual customizing functions.) Though this is but one example, it reveals how the SDG was able to anticipate the needs of departmental users and to accommodate those needs proactively in the architecture of the department site. The rapid adoption of the site by so many departments suggests that we were mostly right in our predictions about how departments would want to use the site.

On the other hand, the frustrations experienced by the leaders of the URSSA and GLISTEN projects shows that we were less accurate in our predictions about the needs of project evaluators. When we decided to use the department site to pilot the evaluator site, we based our decision on our analysis of the functional needs of the two sites. The two sites serve the same functions—both kinds of administrators enter and manage lists of faculty, create instruments, lock common questions, and analyze data. In addition, both departments and program evaluators are looking at the same things: what are students learning and how well? Thus, we thought the same interface would work for both sites. What we didn't account for was the fact that because the contexts and audiences were different, they needed different interfaces: departments come with preformed organizational structures that can compensate for a certain amount of dissonance between how the instrument works and how department administrators might want to use it. Those administrators not only enjoy these external contextual resources, they also typically have more tightly and deeply defined (and often more personal) relationships with members of their department, so there are much stronger, more complex social webs they can use—often without even having to think about them—to compensate for gaps in the software. Program evaluators, on the other hand, operate in a relatively impoverished context with far fewer and far less rich social resources, so they need more robust and self-contained software to balance these relative deficits. Thus, one of the most important lessons we learned is that interface design is determined far more by human factors like context, audience and social structures than by functional needs.

A related lesson concerns the value of working with two radically different kinds of projects in our pilot. Working with URSSA and GLISTEN at the same time helped us appreciate both their specific needs and the diversity of those needs because they threw each other into relief. Things that looked like glitches at first appeared as more systemic problems once we started to think about the two projects as pushing inner and outer limits. For example, URSSA's desire to allow faculty to sign themselves into the faculty list initially appeared to contradict GLISTEN's desire to have more control over that same list. Seeing those issues as idiosyncratic and mutually cancelling requests could have caused us to think that there was no serious problem with the software. Thinking about them instead as outer and inner expressions of the limits of our software led us to the conclusion that our interface was too constraining and inflexible and led us to a solution that accommodated both audiences and made the software easier for everyone to use. Our second lesson then, is that working simultaneously with widely diverse audiences in a pilot improves interface design because triangulation leads to better solutions than serial dialogues.

Although this pilot experience has in some ways been a bumpy ride and while we certainly regret the frustration our initial interface caused our colleagues at URSSA and GLISTEN, the SDG considers the pilot quite successful. Discovering points of weakness is exactly what pilots are for, so success is determined not by whether or not things went smoothly, but rather by what one learns. In this pilot, the SDG learned the answer to two very important questions. We learned that the SALG can provide a useful foundation for a site for program evaluators, and we learned how to change the interface to make it effective for these very different kinds of multi-institutional evaluations.

Those changes to the interface highlight the final three lessons we learned about how to design interfaces for large-scale multi-institutional evaluation. First, the interface has to be easy for individual faculty to learn or they won't participate. Or perhaps worse, they will start to participate, get things wrong, pollute the dataset and then quit. Building the site so that faculty didn't have to learn a new interface as they worked with departmental and evaluator instruments was exactly the right decision. Conversely, distributing special instructions to GLISTEN faculty for how to access and reuse GLISTEN instruments worked poorly. From this we learned that although preserving a familiar interface as one adds functions to the site is a good idea, it is better to modify that interface slightly to accommodate new functions than to keep the interface exactly the same when doing so makes the user's overall experience of the site more complex and/or more difficult. The second lesson's structure is similar to the first's: building the site such that one instrument can serve multiple purposes is a powerful and attractive feature, but again, it is possible to overdo it. Building the department and evaluator sites on top of the SALG for individual faculty allowed a single instrument to serve the needs of departments and program evaluators without creating appreciably more work for faculty who were already using the SALG. This nested structure curtailed proliferation of instruments and rewarded both individuals and institutions. But here again, our efforts to set the site up so that it created no extra work for faculty ended up making so much extra work for administrators that they had no choice but to pass much of it on to their faculty (e.g., extra instructions and teleconferences). Again, making a few modest changes to the interface would have made it easier to use and more productive on both sides. Finally, those modest changes that will appear on the new SALG site will be worth making not only because they will make it easier to use the SALG site to evaluate large-scale projects in STEM education and large-scale educational reform initiatives like URSSA, GLISTEN and SENCER, but because they will ultimately make the site easier for everyone to use by keeping the interface familiar but not identical and by leveraging those few changes to the interface to add powerful new capabilities.

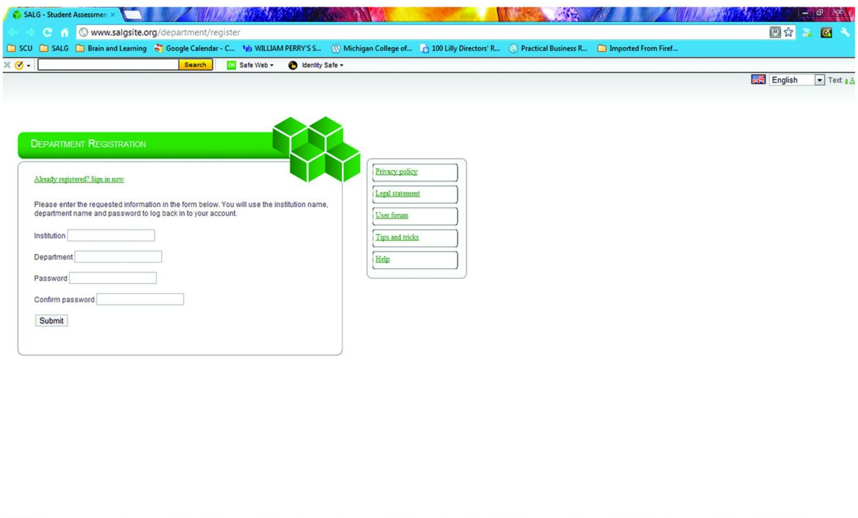
Acknowledgments

First and foremost, I thank Glenn Odenbrett of the National Center for Science and Civic Engagement for vast and important work he did as the Director of the GLISTEN project and for the careful and always-useful feedback he provided to the SDG as he piloted the GLISTEN-SALG. It was largely through his experiences and reports that the SDG discovered many of the key lessons explained in this chapter. I thank Glenn also for his vital contrbutions to this manuscript; his insights and voice greatly enriched the analysis and the arguments. I am grateful as well to my colleague, Andrea Pappas, for her perspicacious insights on design principles, many valuable discussions about this manuscript, and her patient and perceptive editing. I also wish to thank the SALG Development Group for their tireless work in developing the department and evaluator sites into useful tools that can help faculty improve their teaching. Finally, I would like to acknowledge the National Science Foundation for supporting this work (TUES/CCLI grant # 0920801).

Publication Date (Web): December 18, 2012 | doi: 10.1021/bk-2012-1121.ch014

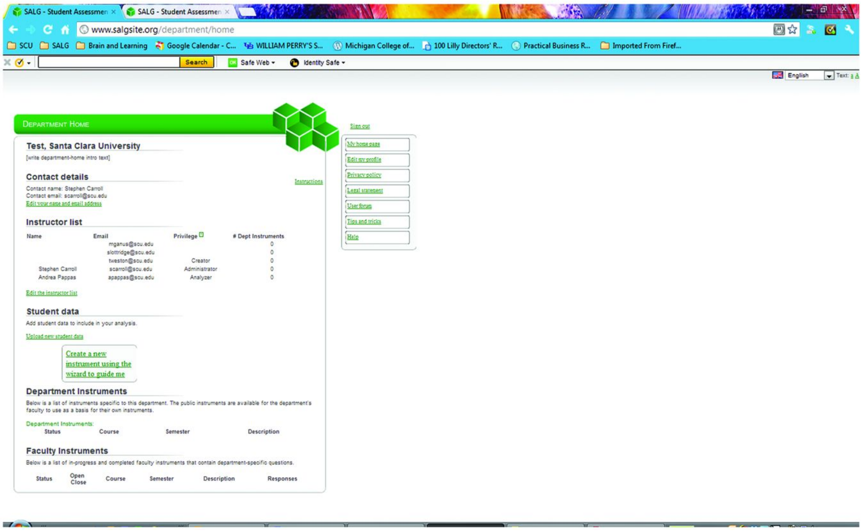
Appendices

Appendix 1: Department Site Registration

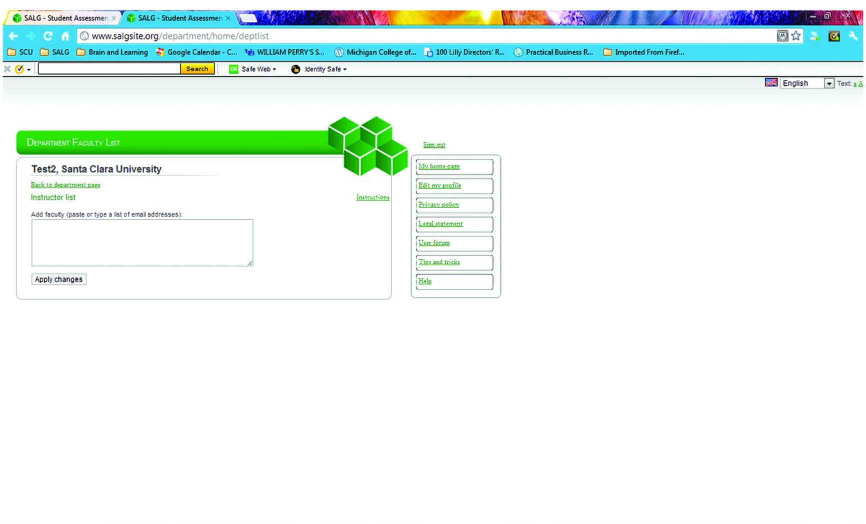


In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Appendix 2: Department Site Home

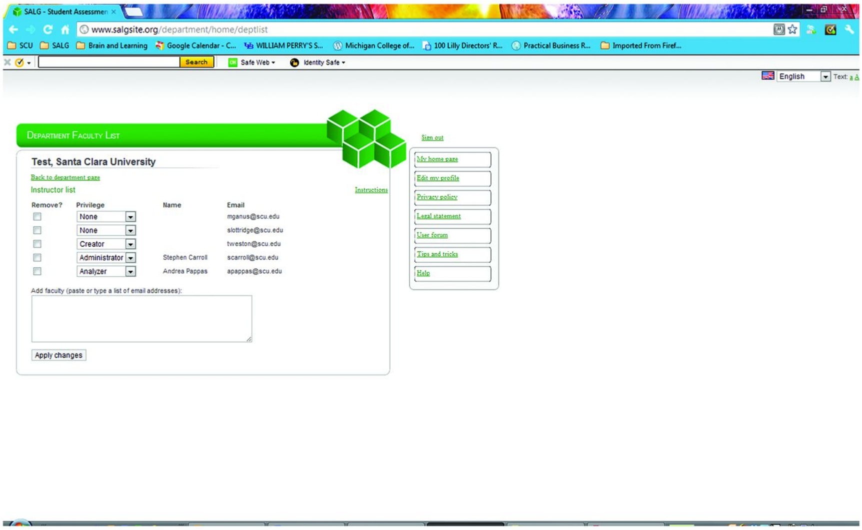


Appendix 3: Department Site Faculty List—Blank

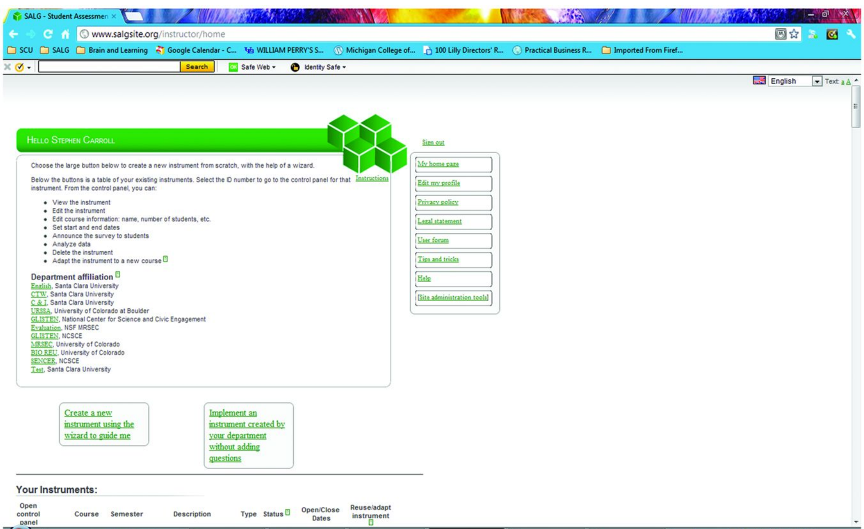


In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Appendix 4: Department Site Faculty List—Populated

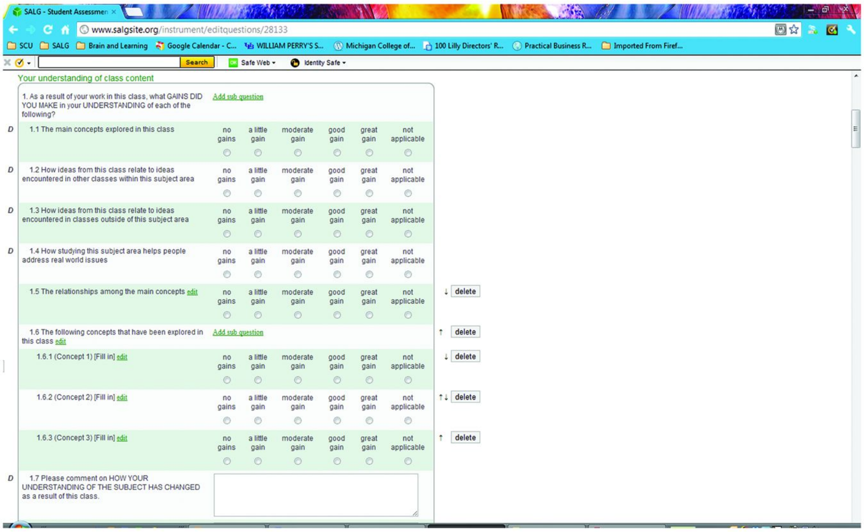


Appendix 5: Department Membership

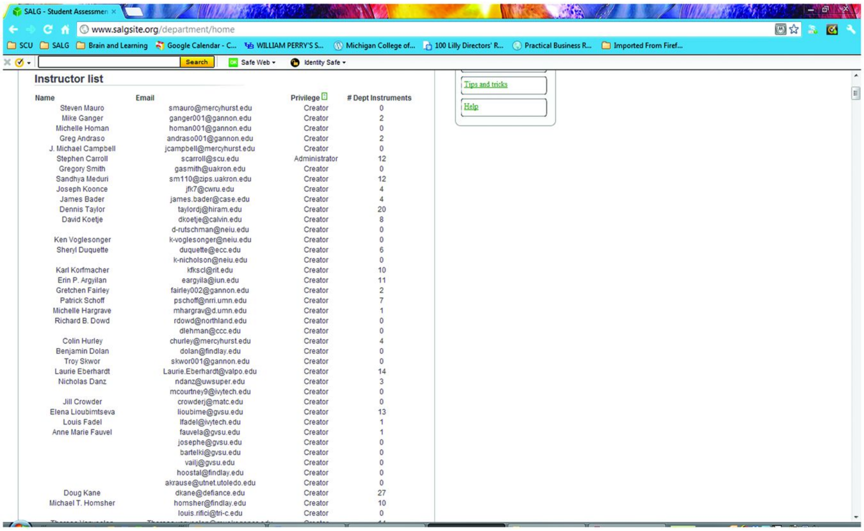


In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Appendix 6: D Questions



Appendix 7: GLISTEN Faculty List

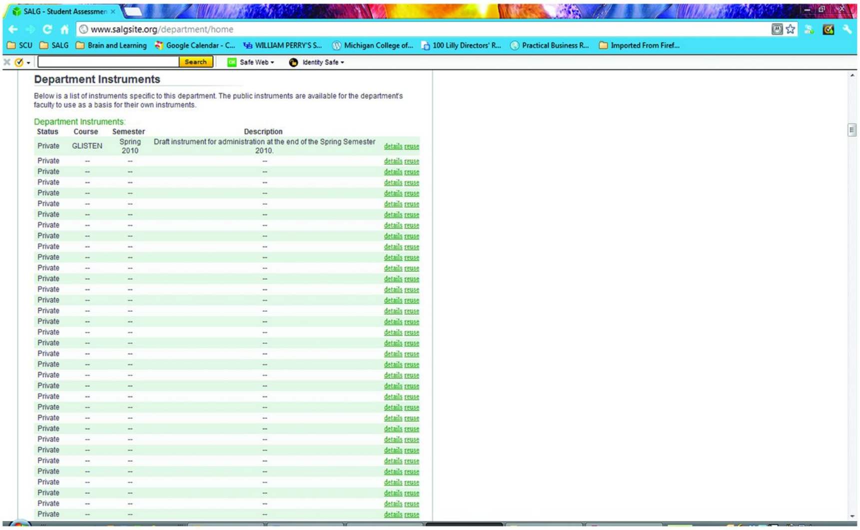


Instructor list

Name	Email	Privilege	# Dept Instruments
Steven Mauro	smauro@mercyhurst.edu	Creator	0
Mike Ganger	ganger001@gannon.edu	Creator	2
Michelle Homan	homan001@gannon.edu	Creator	0
Greg Andraso	andraso001@gannon.edu	Creator	2
J. Michael Campbell	jcampbell@mercyhurst.edu	Creator	0
Stephen Carroll	scarroll@scu.edu	Administrator	12
Gregory Smith	gasmith@uakron.edu	Creator	0
Sandhya Meduri	sm110@zips.uakron.edu	Creator	12
Joseph Koonce	jfk7@cwru.edu	Creator	4
James Bader	james.bader@case.edu	Creator	4
Dennis Taylor	taylordj@hiram.edu	Creator	20
David Koetje	dkoetje@calvin.edu	Creator	8
	d-rutschman@neiu.edu	Creator	0
Ken Voglesonger	k-voglesonger@neiu.edu	Creator	0
Sheryl Duquette	duquette@ecc.edu	Creator	6
	k-nicholson@neiu.edu	Creator	0
Karl Korfmacher	kfkscl@rit.edu	Creator	10
Erin P. Argyilan	eargyila@iun.edu	Creator	11
Gretchen Fairley	fairley002@gannon.edu	Creator	2
Patrick Schoff	pschoff@nrri.umn.edu	Creator	7
Michelle Hargrave	mhargrav@d.umn.edu	Creator	1
Richard B. Dowd	rdowd@northland.edu	Creator	0
	dlehman@ccc.edu	Creator	0
Colin Hurley	churley@mercyhurst.edu	Creator	4
Benjamin Dolan	dolan@findlay.edu	Creator	0
Troy Skwor	skwor001@gannon.edu	Creator	0
Laurie Eberhardt	Laurie.Eberhardt@valpo.edu	Creator	14
Nicholas Danz	ndanz@uwsuper.edu	Creator	3
	mcourtney9@ivytech.edu	Creator	0
Jill Crowder	crowderj@matc.edu	Creator	0
Elena Lioubimtseva	lioubime@gvsu.edu	Creator	13
Louis Fadel	lfadel@ivytech.edu	Creator	1
Anne Marie Fauvel	fauvela@gvsu.edu	Creator	1
	josephe@gvsu.edu	Creator	0
	bartelki@gvsu.edu	Creator	0
	vailj@gvsu.edu	Creator	0
	hoostal@findlay.edu	Creator	0
	akrause@utnet.utoledo.edu	Creator	0
Doug Kane	dkane@defiance.edu	Creator	27
Michael T. Homsher	homsher@findlay.edu	Creator	10
	louis.rifici@tri-c.edu	Creator	0

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

Appendix 8: GLISTEN Department Instruments



Department Instruments

Below is a list of instruments specific to this department. The public instruments are available for the department's faculty to use as a basis for their own instruments.

Department Instruments:

Status	Course	Semester	Description	
Private	GLISTEN	Spring 2010	Draft instrument for administration at the end of the Spring Semester 2010.	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse
Private	--	--	--	details reuse

Appendix 9: GLISTEN Faculty Instruments

Faculty Instruments

Below is a list of in-progress and completed faculty instruments that contain department-specific questions.

Status	Open Close	Course	Semester	Description	Responses	
Completed	Sat Jun 16, 2012 Wed Jun 20, 2012	Geog 101	Spring 2012	Full GLISTEN-SALG	3/10	analyze
Completed	Sun Jun 10, 2012 Tue Jun 19, 2012	Risk Assessment for Risk Manager	Spring 2012=end	This graduate course requires student to chose 3 contaminants of interest, define a hazardous situation with source, pathway and receptors define exposure pathway and concentration in a risk assessment, and then purpose risk reduction strategies and costs to present in a town meeinng.	1/11	analyze
Completed	Wed Jun 13, 2012 Fri Jun 15, 2012	Geog 101	Spring 2012	Baseline GLISTEN-SALG	7/10	analyze
Completed	Thu May 31, 2012 Sun Jun 10, 2012	Risk Assessment for Risk Manager	spring2012	Our Graduate Risk course volunteered to conduct four sampling events on the Lye Creek Sub-watershed of the Blanchard River. This area is the largest contributor of phosphorus and sediment to the Great Lakes. We took samples for PO4, pH, ORP, location, time , flow rate, depth, width, temperature, and barometric pressure under chain of custody.	0/0	analyze
Completed	Thu May 24, 2012 Tue Jun 05, 2012	Environmental Sampling and Statistics	Fall 2011	This course preares and performss sampling and analysis events. The 2011 events are focused on a subwatershed of the Blanchard River in NW Ohio named the Lye Creek Subwatershed.	0/0	analyze
Completed	Fri May 04, 2012 Fri May 25, 2012	ENS 201 Intro to Environmental Science	Spring 2012	Introduction to Environmental Science course for freshmen	15/22	analyze
Completed	Tue May 15, 2012 Thu May 24, 2012	Great Lakes/ES Capstone	Spring	Follow-up Survey for Great Lakes I, II and ES Capstone Seminar for the Capstone Project	2/15	analyze
Completed	Wed May 09, 2012 Sun May 20, 2012	ENS201	Winter 2012	Introduction to Environmental Studies and Sustainability	0/40	analyze
				This class provides an		

References

1. The SALG is a free, reliable and valid instrument for assessing student learning. It includes both baseline (beginning of term) and end-of-term instruments, and is available at www.salgsite.org. The SDG comprises Stephen Carroll—PI (Santa Clara University), Robert Mathieu (University of Wisconsin, Madison), Elaine Seymour (University of Colorado, emerita), and Tim Weston (University of Colorado). Susan Lottridge—formerly Sue Daffinrud—(Pacific Metrics) left the SDG in 2009. Melissa Ganus (Ganus Research) joined the group in 2011.
2. Scope creep (sometimes called feature creep, mission creep or requirement creep) refers to unplanned or uncontrolled changes to a project's scope, often caused by adding features or requirements or applications that were not in the original project plan.
3. Key members of Seymour's research team included Carolie Coates, Heather Thiry, Tim Weston and Susan Lottridge. PIs for ChemLinks Coalition: Making Chemical Connections, were Brock Spencer (Beloit College), James Swartz (Grinnell College), Sandra Laursen (University 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.
4. This disjunction between SCEs and learning was important to the development of the SALG in two ways. First, the evaluation team observed that the lower scores on SCEs earned by some of the faculty teaching experimental classes led to failed tenure bids despite the fact that their students learned more than those in the control classes—whose instructors earned higher scores on SCEs. Seymour's team wanted to create an instrument that could provide data that would allow teachers to push back against this kind of manifest injustice. Second, the wide (and often exclusive) use of SCEs to determine teaching scores in rank, tenure and promotion (RTP) decisions creates a powerful counterincentive to do the kinds of experiments—particularly ones that challenge students' preconceptions—that can genuinely improve teaching and learning. Part of the purpose of the SALG is to facilitate this kind of research by developing a valid and reliable instrument that can document and defend such research and its results.
5. Seymour, E.; Wiese, D.; Hunter, A.; Daffinrud, S. *Creating a Better Mousetrap: On-line Student Assessment of their Learning Gains*; University of Colorado, Bureau of Sociological Research: Boulder, CO, 2000. http://www.aacu.org/resources/sciencehealth/documents/Mousetrap.pdf (accessed July 11, 2012).
6. Weston, T.; Seymour, E.; Lottridge, S.; Thiry, H. *The Validity of the SENCER-SALG*; ATLAS Evaluation Report: Boulder, CO, 2005.
7. For more information on the history and structure of the SALG instrument, see Carroll, S. Engaging Assessment: Using the SENCER-SALG to Improve

Teaching and Learning. In *Science Education and Civic Engagement: The SENCER Approach*; ACS Symposium Series 1037; Sheardy, R., Ed.; American Chemical Society: Washington, DC, 2010; Chapter 10.

8. While the primary audience for the SALG was, and remains, faculty in STEM disciplines, the SDG has made flexibility and broad applicability major priorities as the SALG has developed. And because the SALG's categories of goals and pedagogical elements cut across disciplinary boundaries, faculty in many non-STEM disciplines such as art history, German and philosophy, use it.
9. The first version of the SALG website had no restrictions and the SDG discovered that many people treated the SALG site as a kind of free Survey Monkey, erasing all the questions and repopulating it with questions of their own. Unfortunately, many of them recreated traditional SCEs on the SALG website and then represented their surveys as SALGs. This created confusion and made it more difficult for the target audience to understand the SALG's identity and value.
10. SENCER (Science Education for New Civic Engagements and Responsibilities), a program run by the National Center for Science and Civic Engagement, aims to improve science education by connecting it to complex and capacious—and often unresolved—civic issues that directly affect students' lives. For more information, visit www.sencer.net.
11. Weston, T.; Lottridge, S.; Seymour, E.; Coates, C. *Student Assessment of Their Learning Gains: The History and Prospects of a Classroom Evaluation Instrument*; University of Colorado: Boulder, CO, manuscript to be submitted for publication, 2006.
12. The instrument creation process is guided by a wizard. For more information, see Carroll, S. Engaging Assessment: Using the SENCER-SALG to Improve Teaching and Learning. In *Science Education and Civic Engagement: The SENCER Approach*; ACS Symposium Series 1037; Sheardy, R., Ed.; American Chemical Society: Washington, DC, 2010; Chapter 10.
13. Differential routing as a design principle also supports the SDG's goal of preventing inappropriate use of student course evaluation data in RTP decisions.
14. A new version of the SALG site will appear in late 2012 and the advanced analysis features for departments are expected to come online in early 2013.
15. For more information on URSSA, see http://spot.colorado.edu/~laursen/accessURSSA.html. For more information on GLISTEN, see http://www.ncsce.net/Initiatives/GLISTEN.cfm.
16. Ultimately this led to a request for a separate wizard and portal for URSSA because the SALG's deep orientation to courses meant that the instrument creation wizard, users' home pages, and even the SALG's welcome and home pages all included language about courses that didn't really fit with URSSA's research focus. This language confused many novice URSSA users and caused them to worry that they were on the wrong website.
17. For a discussion of differences between real and virtual communities, see Anderson, B. *Imagined Communities*; Verso: London, 1991.

Chapter 15

Applying the Innovation Diffusion Model to SENCERizing the Curriculum: Has SENCER Crossed the Chasm?

Amy M. Shachter*,[1] and Jon J. Barnett[2]

[1]Santa Clara University, 500 El Camino Real, Santa Clara, California 95053
[2]Concordia University Wisconsin, 12800 North Lake Shore Drive, Mequon, Wisconsin 53097
***E-mail: ashachter@scu.edu**

For over ten years, faculty, staff and students have worked to develop SENCER courses across the country. The SENCER approach to science education reform is an innovation in science education. To understand the adoption of the SENCER approach by individual faculty on some campuses and into the mainstream on other campuses, models of innovation diffusion can be explored. In this chapter, the innovation diffusion model will be the framework used to explore SENCERizing the curriculum.

Introduction

For over ten years, faculty, staff and students have worked to develop SENCER courses across the country (*1*). In some cases, as described in this book, the SENCER approach has moved beyond individual courses and has been applied to the development of general education programs and to courses within science majors. The SENCER approach to science education reform is an innovation in science education. To understand the adoption of the SENCER approach by individual faculty on some campuses and into the mainstream on other campuses, models of innovation diffusion can be explored. In this chapter, the innovation diffusion model (*2*) will be the framework used to explore SENCERizing the curriculum. This model has been applied to analyze education reform (*3*), faculty development (*4*) and educational technology projects (*5*). A brief overview of the SENCER project will be followed by a description of the innovation of diffusion

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

model in general and as applied to the SENCER project. Finally, a discussion of strategies for moving SENCER into majority or mainstream curricula will be presented.

The SENCER Project

Science Education for New Civic Engagements and Responsibilities (SENCER) is an NSF-supported national science education reform project whose mission is to improve science education by helping to develop and strengthen efforts that teach *through* complex social issues *to* the basic science necessary *to comprehend and intelligently act on them.* The project focuses on undergraduate courses for non-science majors. The approach has been extended into courses within science majors on some campuses. The project articulates a general philosophy of *curricular change that is linked to civic engagement and public policy* and is focused on *assessing student learning*. The SENCER community currently counts as its members over 1,100 educators and academic leaders as well as students from over 300 colleges and universities from the US and 13 other countries. The main components of the project include SENCER Summer Institutes, model courses, SENCER Centers of Innovation, Backgrounders, Quarterly Newsletter, campus visits, and the journal, *Science Education and Civic Engagement: An International Journal.*

Innovation Diffusion Model

Developed by Rogers, the Diffusion of Innovation Model describes how an innovation is adopted over time (*2*). An innovation can be an idea, approach, or a new technology. According to the model, innovation is adopted following a normal frequency distribution or bell-curve of frequency of adoption versus time (Figure 1). The curve can be divided into five adopter areas. The first 2.5% individuals to adopt (area to the left of the mean minus two standard deviations) are the "innovators". The "early adopters" are the next 13.5% (area between the mean minus one standard deviation and the mean minus two standard deviations). The "early majority" includes the area from the mean to the mean minus one standard deviation and represents 34% of adopters. The early majority adopters are considered the start of the "mainstream". After the mean, the next 34% are considered the "late majority" (those who fall in the area from the mean to the mean plus one standard deviation). The "laggards" are the last 16% of adopters (area to the right of the mean plus an area greater than one standard deviation). The characteristics of adopter categories are important to understanding the diffusion of an innovation.

The first to adopt are called "innovators". These adopters accept risk and revolutionary change. They bring and accept new ideas, are comfortable with uncertainty, and tend to be outside the mainstream. According to Rogers, "the salient value of the innovator is venturesomeness due to a desire for the rash, the daring, and the risky (*2*)." Moreover, "the innovator plays an important role in the diffusion process: that of launching the new idea in the system (*2*)." SENCER

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

innovators may be isolated faculty and may have attended a SENCER Summer Institute (SSI). The early SENCER model developers as well as SSI faculty and principal investigators are "innovators".

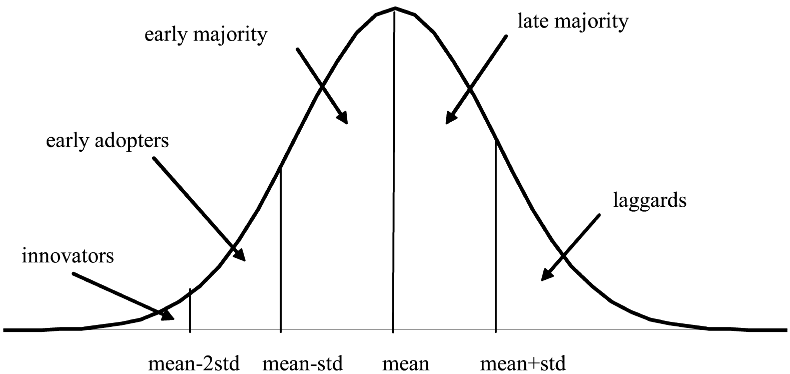


Figure 1. Adopter Categories Based on a Normal Distribution. (Adapted with permission from reference (2). Copyright 2003).

The next group to adopt is the "early adopters". They are visionaries who are typically respected role models, opinion leaders, and change agents. As visionaries, early adopters are "not looking for improvement; they are looking for a breakthrough (*6*)." Early adopters tend to be self-sufficient, willing to experiment and favor revolutionary change. Because they are widely respected, the "early adopter decreases uncertainty about a new idea by adopting it" and "help trigger a critical mass (*2*)." SENCER early adopters are respected faculty who may host campus visits and may be leaders or key members of an SSI team implementing change on campus. Campus change agents fall into this category, including chairs or deans supporting the model. Model developers and those who submit courses for consideration as a model are also early adopters. On a campus with early adopters -- as opposed to a campus having one or two innovators offering a single SENCER course -- several faculty have adopted the approach and begin to offer multiple courses in one or more departments.

The early majority follows the early adopters just before the average individual (just to the left of the mean). The early majority are pragmatists. They deliberate before adopting, seldom lead, and tend to be risk averse. The early majority adopts innovation when benefits are proven and these users may need significant support for adoption. Importantly, "they are content to wait to see how others are making out before they buy in themselves. They want to see well-established references before investing substantially (*6*)." The early majority represents the start of the "mainstream". SENCER early majority may be faculty who have been on multiple SSI teams. As SENCER moves in the "mainstream" on a campus, faculty begin to develop multiple SENCER courses *in at least one department.* Discussion and interest begins to gain momentum to *move the SENCER approach into the broader general education curriculum across the sciences. Some innovators and early adopters have begun testing the approach in major courses.* Faculty within the early majority might develop new models, publish SENCER results in peer-reviewed journals and host regional meetings through the SENCER Centers of Innovation.

The later half of mainstream adoption involves the late majority. Members of the late majority are skeptical and cautious. They tend to adopt just after the average when adoption is due to necessity or peer pressure. Uncertainty must be removed or minimized before an innovative approach is considered safe to adopt by the late majority. Moreover, "they wait until something has become the established standard, and even then, they want to see lots of support (*6*)." The SENCER late majority would involve *SENCER integrated as approach throughout general education curriculum* and to *SENCERization of majors curriculum.* Wide-spread, mainstream adoption requires the participation and buy-in of the late majority faculty for sustainable change.

Finally, the last to adopt are the laggards. They are suspicious of innovations and change agents and will only adopt when they are certain the new idea will not fail. Laggards follow after the innovation has been adopted by the "mainstream".

Diffusion, the Chasm and Attributes of Innovations

When considering the adoption of a new innovation, the curve may actually be discontinuous with a "chasm" in the diffusion curve (Figure 2). Moore identifies "the deep and dividing chasm that separates the early adopters from the early majority (*6*)." Many new ideas, approaches and technologies never move beyond the chasm into the mainstream. The willingness of the early adopters to accept change and work through the bugs and glitches that may accompany the adoption on an innovation is often not found in the early majority who look to minimize disruption and favor an innovation that works with minimal support. Within SENCER, there are many cases of SSI teams and SENCER innovators whose work remains isolated or, in some cases, discontinued. On those campuses, the SENCER approach never moves into the broader science or general education curriculum and falls into the chasm. What factors can effect the adoption of an innovation? Crossing the chasm may indeed be a key factor in the broader adoption on a campus. How can one strategically move the adoption of an innovation across the chasm? Considering the perceived attributes of innovation as related to the diffusion of innovation may shed light to ways to address this question.

Rogers identified five perceived attributes of an innovation that are strongly correlated with the rate of adoption of the innovation: relative advantages, compatibility, complexity, trialability, and observability (*2*). Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes (*2*)" or better than current practice. According to Rogers, "diffusion scholars have found relative advantage to be one of the strongest predictors of an innovation's rate of adoption (*2*)." Compatibility is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters (*2*)." Compatibility with previously adopted ideas is also important to some adopters, especially within the mainstream. In predicting rate of adoption, compatibility is "somewhat less important" than relative advantage (*2*). Complexity refers to how difficult an innovation is to use or understand. As one might predict, the more complex an innovation, the less likely it will be adopted. In overcoming perceived complexity, support structures may be key to facilitating adoption. Trialability "is the degree to which an innovation may be experimented with on a limited basis (*2*)." Importantly, "if an innovation can be designed so as to be tried more easily, it will have a more rapid rate of adoption (*2*)." Trialability is important for early adopters while late adopters prefer a tested, working approach. Lastly, observability "is the degree to which the results of an innovation are visible to others (*2*)." Considering the possible implications for optimizing the adoption of the SENCER approach, the relative advantage and compatibility must be clear, complexity should be minimized, opportunities to experiment and try curricular elements should be made available and the results should be assessed and disseminated for others to observe and consider.

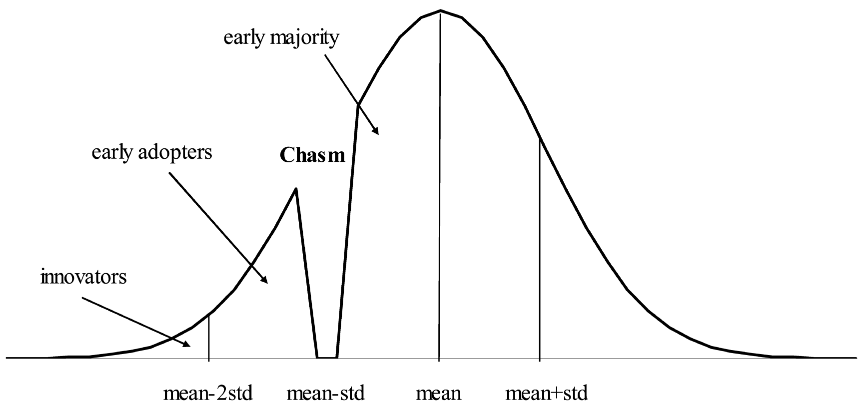


Figure 2. The Chasm may separate the Early Adopters from the Early Majority. (Adapted with permission from reference (6). Copyright 2006).

The relative advantage of the SENCER approach often "clicks" for many innovators and early adopters. The SENCER approach of teaching *through* complex social issues *to* the basic science necessary *to comprehend and intelligently act on them* is perceived as providing a relative advantage over traditional science education by enhancing student engagement and improving learning. The evaluation results for the SENCER project (*1*) as well as campus-based success stories also make a case for relative advantage for later adopters. In addition, aligning with a successful, long-running National Science Foundation funded-project like SENCER is perceived by many as a relative advantage for supporting current efforts as well as achieving curricular reform on campus. Lastly, many faculty come to SENCER already using the approach but not having "named" their work. Joining the SENCER community provides a validation of efforts and, hence, defines a relative advantage for their hard work.

Compatibility is a fundamental factor for the adoption of the SENCER approach. For the SENCER project to be successful in a particular scientific community, there has to exist a culture of service and civic responsibility so that

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

this project can address the beliefs and needs of that community. Though we can certainly say that service and civic responsibility are *concerns* of all scientists that does not mean, necessarily, that there is a strong *culture* related to these attributes within the faculty at all schools. Hence, we can really only expect SENCER to "take root" in communities where these are not only *valued* but where they are actively taught and sought after. Such value is often represented in the general education requirements of an institution. Over the past ten years or so, civic engagement has become a central element of general education requirements in many US colleges and universities. Consequently, many institutions have looked for ways to integrate civic engagement into courses, many with a particular emphasis on science courses. SENCER has been well positioned to support such efforts. Many campuses such as Butler University, University of North Carolina at Ashville and, most recently, WestPoint have used the SENCER approach to facilitate reform of the general education requirement. Other successes are described in this book as well as the earlier ACS Symposium Series focused on the SENCER approach (*7*).

Complexity should not be overlooked in considering the adoption of the SENCER model. For SENCER, in many ways, the complexity lies in faculty development that is, building faculty expertise and confidence to explore the social dimensions of science and providing support for civic engagement. Innovators and early adopters often require little to get started but to cross the chasm and move into the mainstream faculty development and support structures are necessary.

Trialability is a hallmark of SENCER. The SENCER models are designed to offer opportunities to adapt small changes such as a case study or letter to a congressperson. In addition, SENCER single "one-off" courses can be offered by individual science faculty to a body of interested students. These innovators can try the courses out and, upon successful completion, can spread the word regarding the merits of the program through their social networks within the school. However, in order to get to this point there must be initial buy-in from the administration. In order to offer a course, a faculty member has to get approval from someone in an administrative role within the university. This can be a difficult idea to sell since it increases the work load on that faculty member, which could require that a faculty member spend less time teaching the standard courses offered within his or her discipline. Therefore, the culture of service and civic responsibility has to have not only spread throughout the faculty but also to the administration.

Observability is an interesting challenge when considering the SENCER project because it is a predominantly knowledge-based innovation, meaning that it is an innovation that has little or no "hardware" associated with it. As Lu, Quan and Cao note, "innovations in which the software is the dominant component are less observable and have a slower rate of adoption (*5*)."

Evaluations of the success of the SENCER project depend, in part, upon whether one looks at the micro scale or macro scale. Also, it depends upon how the micro and macro scales are defined. If one steps back to the extreme macro scale and considers the entire US educational system, it is clear that the SENCER project has not crossed the chasm at the macro scale. At this level, the micro scale might consist of individual universities. On the micro scale, we would again say that success is limited. If, however, we consider the macro scale to be the university level for universities at which the SENCER project has been initiated and the micro scale the individual adopter/course level, the success level is quite different. The success at the micro level in this case is very high, since by definition we are looking at schools where the SENCER project is, at least in part, in place. At the macro scale, we see mixed degrees of success, as there are schools where the project has certainly crossed the chasm and moved beyond the individual course level to much higher levels of development, while there are other institutions where SENCER seems to be "stuck" in the course level of development.

Conclusion

In considering categories of adopters and the chasm, innovators and the first early adopters typically see the relative advantage of an innovation and adopt the innovation before "the chasm". To move across the chasm and into the mainstream (early and late majority), the attributes of innovation that are key to address are compatibility, complexity, trialability, and observability. To accelerate crossing the chasm on individual campuses, those involved in SENCER projects may consider focusing on fostering local or regional references and addressing local or regional issues of *compatibility, complexity, trialability, and observability.*

References

1. Burns, W. D. SENCER in Theory and Practice: An Orientation and Introduction. In *Science and Civic Engagement: The SENCER Approach*; Sheardy, R.; Ed.; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010; Chapter 1.
2. Rogers, E. M. *Diffusion of Innovations*, 5th ed.; Free Press: New York, 2003.
3. Warford, M. K. Testing the diffusion of innovation in education model (DIEM). *Innovation J.* **2005**, *10* (3), Article 32.
4. Jordan, C.; Doherty, W. J; Jones-Webb, R.; Cook, N.; Dubrow, G; Mendenhall, T. J. Competency-based faculty development in community-engaged scholarship: A diffusion of innovation approach. *J. Higher Educ. Outreach Engagement* **2012**, *16*, 65–95.
5. Lu, Y., Quan, J.; Cao, X. The perceived attributes of wi-fi technology and the diffusion gap among university faculty members: A case study. *Commun. Assoc. Inf. Syst.* **2009**, *24*, Article 5. http://aisel.aisnet.org/cais/vol24/iss1/5.
6. Moore, G. A. *Crossing the Chasm*; Collins Business Essentials: New York, 2006.
7. Sheardy, R.; Ed. *Science and Civic Engagement: The SENCER Approach*; ACS Symposium Series 1037; American Chemical Society: Washington, DC, 2010.

Subject Index

D

E

F

G

H

I

K

L

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

M

N

O

P

Q

R

S

T

In Science Education and Civic Engagement: The Next Level; Sheardy, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2012.

U

W

Y