Evaluation of Science Education for New Civic Engagements and Responsibilities (SENCER) Project

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Executive Summary

The evaluation of the *Science Education for New Civic Engagements and Responsibilities* (SENCER) project is an NSF-sponsored, three-year effort to assess the impact of SENCER courses on participating students and faculty. Evaluators revised and validated the SENCER-SALG online survey, analyzed student data from the survey, collected course descriptions from SENCER faculty, and linked faculty course descriptions to student survey responses.

Evaluators found the following:

- Over 10,000 students answered questions from the SENCER-SALG online survey. When students across SENCER courses rated instructional and learning activities that "helped them learn," the results painted a complex picture of reform efforts. High ratings for areas such as "addressing real world issues" and "the interplay between civic and scientific issues" suggest that instructors' use of civic content to frame science is engaging students and is perceived as helpful for their learning. However, students also rated lecture and "learning science facts" highly, supporting a more traditional pedagogical approach.

- Students in SENCER classes rated their confidence in science skills, interest in science and civic behavior. Students gained the most from pre to post surveys in the areas of science literacy, followed by general course skills. This pattern of gains is in line with efforts by SENCER to encourage awareness of the link between civic issues and scientific content. When asked to rate their interest in pursuing "advanced" science activities such as joining science clubs or attending graduate school, 10% of students who had little or no interest on the pre in taking future science courses reported they were highly or extremely interested in taking courses on the post. While few students reported engaging in civic activities such as attending hearings or writing letters to the editor before courses, roughly a fifth of the students who had never engaged in civic activities said they were more likely to participate in these activities after course completion. This proportion was higher in courses with service learning components.

- When specific demographic groups were analyzed separately on their responses to the SENCER-SALG, women gained more than men, and non-science majors gained more than science majors on many of the items and composite variables. This is encouraging evidence given that females and non-science majors have traditionally been underserved or overlooked in many university science programs.

- The incorporation of innovative instructional methods predicted pre/post gains on the SENCER-SALG. The inclusion of projects, group work, presentations and field-work were associated with greater gains in confidence in both science literacy and general science skills.

- An important outcome of the SENCER project was the development and validation of the SENCER-SALG. Use of the survey has grown steadily from the beginning of the project. Validity evidence for the survey includes factor analysis showing relatively independent factors corresponding to item blocks, and criterion matches with academic test scores. Perhaps most important to the continuation of the survey were findings from faculty that they used what they learned from the survey to make meaningful changes to their instruction.

- Faculty praised SENCER for providing the support they needed to implement their courses. Through workshops at the summer institute, publications, models and outreach, SENCER was identified by 63% of the instructors as actively helping their course implementation. Ninety-two percent of instructors believed their courses would be continued in the future, and 80% considered their course part of the permanent curriculum at their institution.

- Instructor recommendations for SENCER administrators included intensified outreach activities, both at a national level, and locally through direct contact with institutional representatives. Legitimizing reform efforts to peers and deans through outreach was also cited as an important activity that SENCER currently performs.

- Analysis of linked student and faculty data showed how content and methods interact with student confidence and interest in science. Case-based and survey-based courses were roughly equal in gain on science literacy items. For confidence in general science skills, students in survey-based courses gained more than case-based courses. This result may be due to greater emphasis placed on traditional academic content in these courses.

- SENCER instructors also wanted more opportunities to network with other instructors. Some wanted clusters to be more active in helping faculty interact with their peers throughout the school year, and felt that email was not enough to sustain this contact. Instructors new to SENCER especially wanted to interact with veteran SENCER faculty who could provide nuts-and-bolts advice on implementing and teaching a SENCER course.

- Instructors provided a detailed picture of their course content and practices. From these descriptions it was evident that SENCER's goal of encouraging faculty to teach courses with civic content and innovative pedagogy is a reality. How SENCER courses are implemented varied; almost half of faculty organized courses around specific case-based themes with a single topic used to frame science content, a model seen in many SENCER publications and SSI presentations. Other faculty had a broader approach; some courses focused explicitly on the link between science and society while others retained basic science courses but added a civic component in as a module or special topic.

- SENCER faculty embraced the use of innovative pedagogical methods such as field activities, group work, projects and presentations. While most instructors also practiced traditional methods like lecture, multiple choice tests and quizzes, those using the case-based approach were more likely to incorporate projects, presentations and field activities into their courses. Service learning and community projects (used by 33% of the instructors) were also more likely to be incorporated into case-based courses. Those teaching courses with service learning also tended to practice innovative pedagogy and have learning goals that focused on societal and ethical issues.

- Faculty identified an array of personal and structural implementation barriers to course implementation, although a majority were able to implement and sustain courses. Barriers included insufficient time to plan and implement new courses, and active resistance to reform practices from colleagues, administrators and students. One area where SENCER has helped, and could help in the future, is by lending the weight of a national organization to efforts to convince reluctant colleagues that reform-based approaches are worthwhile and effective.

- Many of the facilitators and barriers mentioned by faculty are out of the control of an external organization like SENCER. However, any facilitation of extra time through money for course buyouts (i.e., through the NSF) addresses some of the more practical logistical concerns of instructors. An awareness of the obstacles facing instructors as they implement courses is also important; SSI workshops devoted to overcoming common implementation challenges faced during reform could educate faculty on this topic.

Introduction & Context for Evaluation

The evaluation of the *Science Education for New Civic Engagements and Responsibilities* (SENCER) project is an NSF-sponsored, three-year effort to assess the impact of the SENCER instructional approach. Much of the focus of the evaluation has been on developing and revising the SENCER-SALG online survey. The survey helps instructors improve their courses, and assesses outcomes important to the SENCER program. Evaluators also collected descriptions of SENCER courses through surveys, interviews and records.

The SENCER project is an effort to reform undergraduate science instruction in the United States. Leading educators and scientists have called for reform of undergraduate science education, [i] and national and localized campus reform efforts[ii] have challenged the traditional model of science teaching characterized by extended lectures and assessment that tests memorization of discrete facts. Encouraging undergraduate non-science majors to be more engaged in science through changes in individual course curricula was an important initial goal for SENCER. Through its summer institute, workshops, published materials and other activities, SENCER encourages an approach to teaching science that frames science content with social and civic themes. In SENCER courses, instructors link social issues and scientific inquiry, and engage in instruction that moves away from the traditional lecture format toward the use of field activities, learning technology, service learning, collaborative learning and other innovative methods. SENCER instructors also teach interdisciplinary courses, focus on local civic issues, and link science, engineering and mathematics to individual student lives.

Evaluation Questions

SENCER was initially conceived as a development project that aimed at making science "more real" through the creation of SENCER models, and encouraging better science teaching at the SENCER Summer Institute. To assess and gain evidence about this effort, evaluators helped revise and administer the SENCER - *Student Assessment of Learning Gains* (the SENCER –SALG), a survey of students enrolled in hundreds of SENCER courses asking them to rate (pre and post) their confidence and interest in science skills and activities. Additionally, students rated course activities that "helped them learn," and described civic activities they engaged in over the past year. Detailed information was also gathered about the content and instructional practices of SENCER instructors through surveys, interviews and records. When possible, these two strands of information were linked to learn how implementation of courses related to student responses to the survey. The overall goal of collecting the data was to learn how SENCER courses followed the goals and principles of the SENCER organization, and how students in these courses assessed their own learning.

The SENCER evaluation posed a challenge for evaluators. A central question for most educational program evaluations is educational efficacy: *Does the program improve student learning?* For SENCER, this question could not be answered directly given the diversity of disciplines, sub-disciplines, class levels and assessment methods and assessment measures used by SENCER instructors. The wide range of courses, coupled with a lack of clearly matched comparison courses with similar content and measures, made it almost impossible to conduct a traditional experimental or quasi-experimental outcome based study.

The evaluation questions answered by this data include:

1. What are the characteristics of SENCER courses?

a. How does social/civic content frame and support science learning?
b. What types of learning objectives, instructional techniques, assessment and perceived outcomes are described by instructors?
c. What types of service learning occur in SENCER courses?
d. How do content, instruction and service learning relate to each other?

2. How do SENCER instructors perceive the SENCER program? What implementation facilitators and obstacles are present for instructors?

a. What were instructor assessments of the SENCER program? Which SENCER program activities would instructors like to see improved?
b. What helped implementation of SENCER courses?
c. What implementation barriers were perceived by instructors?

3. Across all courses, what activities "help students learn," and are these activities consonant with the SENCER approach?

a. Do students rate civic/social learning activities highly in comparison with more traditional activities?

4. In which areas of the SENCER-SALG do students gain more or less in ratings of skills, interests and activities?

a. What are the overall results of the SENCER-SALG over five semesters?

5. Do specific demographic groups gain more or less from pre to post on SENCER variables? Who benefits the most from SENCER courses?

a. Do women tend to gain more than men on SENCER-SALG items?
b. Do results differ for science v. non-science majors?
c. Which demographic factors predict gain?

6. Are specific approaches in content, instruction and implementation associated with more less gain from pre to post on SENCER variables?

a. How were content and instructional methods related to gains?
b. How did implementation affect gain?
c. How did class size relate to gain and implementation?
d. Were students in courses with a service learning component more likely to say they would engage in these activities than students who did not have service learning?

7. How can the SENCER-SALG be best utilized by instructors? What is the validation evidence for the SENCER –SALG?

Methods

Primary evaluation activities included:

- Collection of descriptive and demographic results from the SENCER-SALG. Data from thousands of students taking SENCER courses, collected over five semesters, provided a rich source of information about SENCER courses and illuminated demographic differences among students.

- Collection of detailed descriptions of SENCER courses from surveys, interviews and records describing their content, course objectives, instructional methods, assessment and perceived outcomes.

- Analysis linking student responses with course descriptions. Because SENCER courses vary substantially given their approach to course content and the way in which courses are implemented, it was possible to learn how student responses to the SENCER-SALG were associated with variation in course design.

- Collection of general evaluation data such as satisfaction with the SENCER program and institutional facilitators/obstacles to course implementation.

- The revision and validation of the SENCER-SALG, an online survey for students who rated course activities for their learning potential, and provided faculty with pre/post comparisons of their confidence in science skills, interest in science and engagement in civic activities.

Data Collection

SENCER-SALG

A range of data collection activities addressed the evaluation areas. Sixty-four instructors in 346 courses with 10,771 students administered the SENCER-SALG online at the beginning and end of each semester. Use of the survey grew each semester, from 711 students in Fall 2003 to 3,682 students in Fall 2005 (see figure 1). The survey is administered online with results electronically sent to instructors after administration. The average time students took for the pre version of the instrument was 6.4 minutes and 9.8 minutes for the post. A majority of the instructors used the survey for one semester; thirty out of sixty-four instructors used the survey more than once (see figure 2). A block of 3123 students came from two semesters of the same large course; many of the analyses in the report are compared with and without these students, and if substantially different the results are reported without their inclusion.[iii]

Figure 1: Number of students each semester taking SENCER-SALG

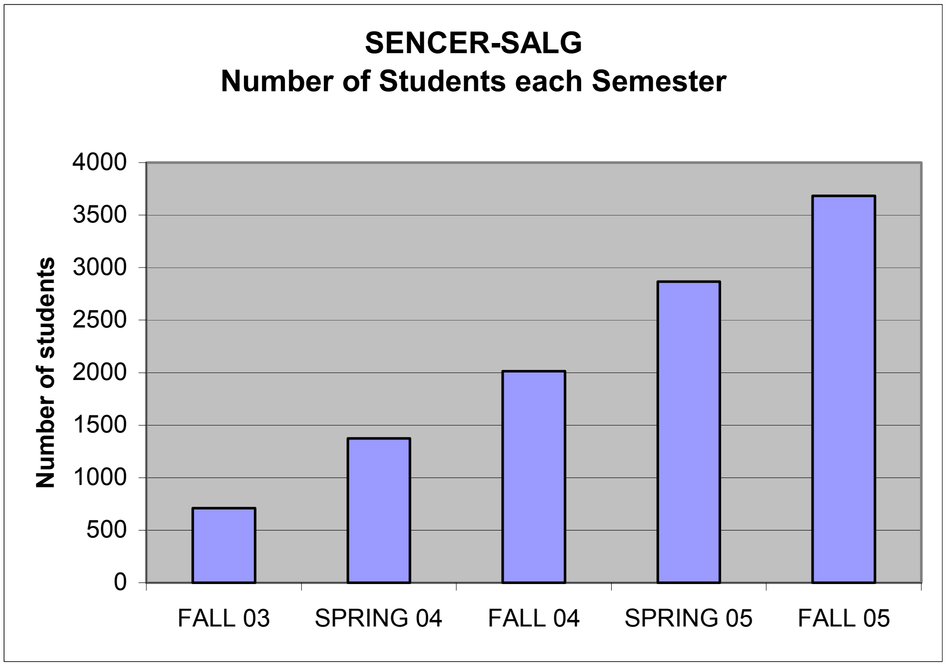
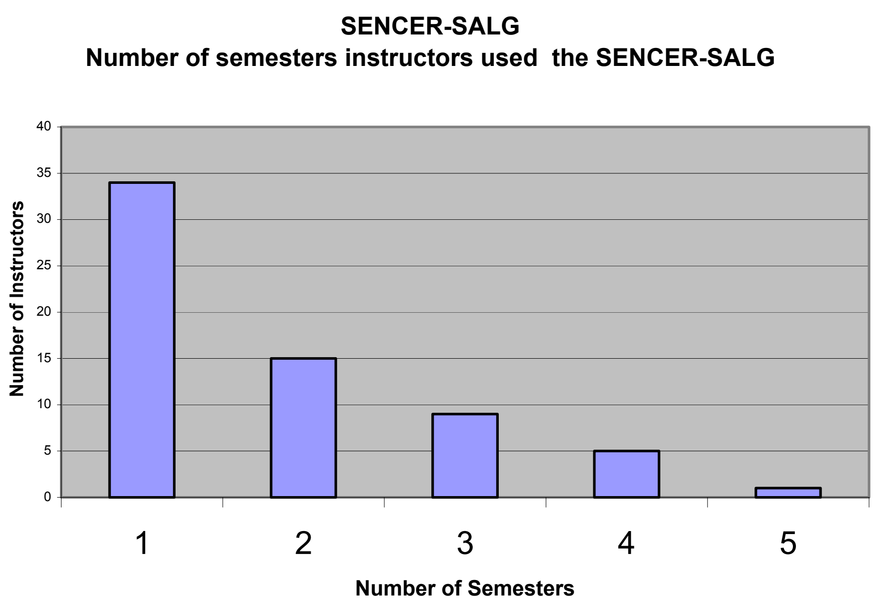


Figure 2: Number of semesters instructors used the SENCER –SALG.



The contents and validity of the SENCER-SALG are discussed in section six and are included in the appendix.

Faculty Surveys & Interviews

We surveyed faculty from a list of 135 instructors who were teaching SENCER courses.[iv] Instructors were almost evenly split between private and public institutions and represented the range of institutional size from less than 1000 students to more than 50,000 students. Detailed descriptions of 107 SENCER courses were gathered through surveys, records and interviews. Surveys asked instructors to describe the disciplinary and civic content of their courses. Instructors also described their learning objectives, instructional methods, assessment and perceived outcomes of the courses, identified what helped and what hindered course implementation, and provided feedback on SENCER project activities. Interviews with 24 2003 and 2004 SSI participants, and with 13 users of the SENCER-SALG in 2004 provided background for the design of the SENCER-SALG and faculty surveys, and allowed thicker descriptions of courses. Twelve follow-up interviews with instructors in 2006 filled in details of survey responses. Analysis of records, SENCER models, course websites and other communications from SENCER faculty provided supplemental information about institutional factors such as size and public/private status of colleges and universities, while giving more detailed information about courses.

Analysis

Analysis procedures for all statistical tests are described in end notes in the results section. Statistical procedures included the use of t-tests, Analysis of Covariance (ANCOVA), and factor analytic techniques. Qualitative data was coded using domain analyses; in some cases data was coded independently by two coders to ensure reliability.

Results

1. What are the defining characteristics of SENCER courses?

Gathering basic descriptions of SENCER courses was fundamental to the evaluation effort. In this section we examined how faculty organized their courses in regards to social and civic content. We also enumerated the learning objectives, instructional methods, assessment and perceived outcomes of SENCER courses reported by instructors, and analyzed how course elements fit together.

How does social/civic content frame and support science learning in SENCER courses?

Through surveys, interviews and records[v] we examined the relationship between basic science content and the civic and/or social content of courses. SENCER model courses were used to illustrate categories. Two general categories of courses were present; 56% of courses were *survey/current issues courses*, 44% were *case-based courses*.

Case-based courses were characterized by specific topics that framed science learning. Examples of these courses (found in the SENCER models) included *Brownfield Action* (Bower), where organic chemistry was linked to a simulated environmental forensic inquiry about toxic waste. In *Tuberculosis* (Fluck), molecular and cellular biology were taught with an interdisciplinary examination of social issues around the disease. For the course *Coal in the Heart of the Appalachian Life* (Mason), chemistry and physics were taught through exploration of the impact of mining in Appalachia. These courses shared a focus on specific, case-based topics as a way to frame basic science content.

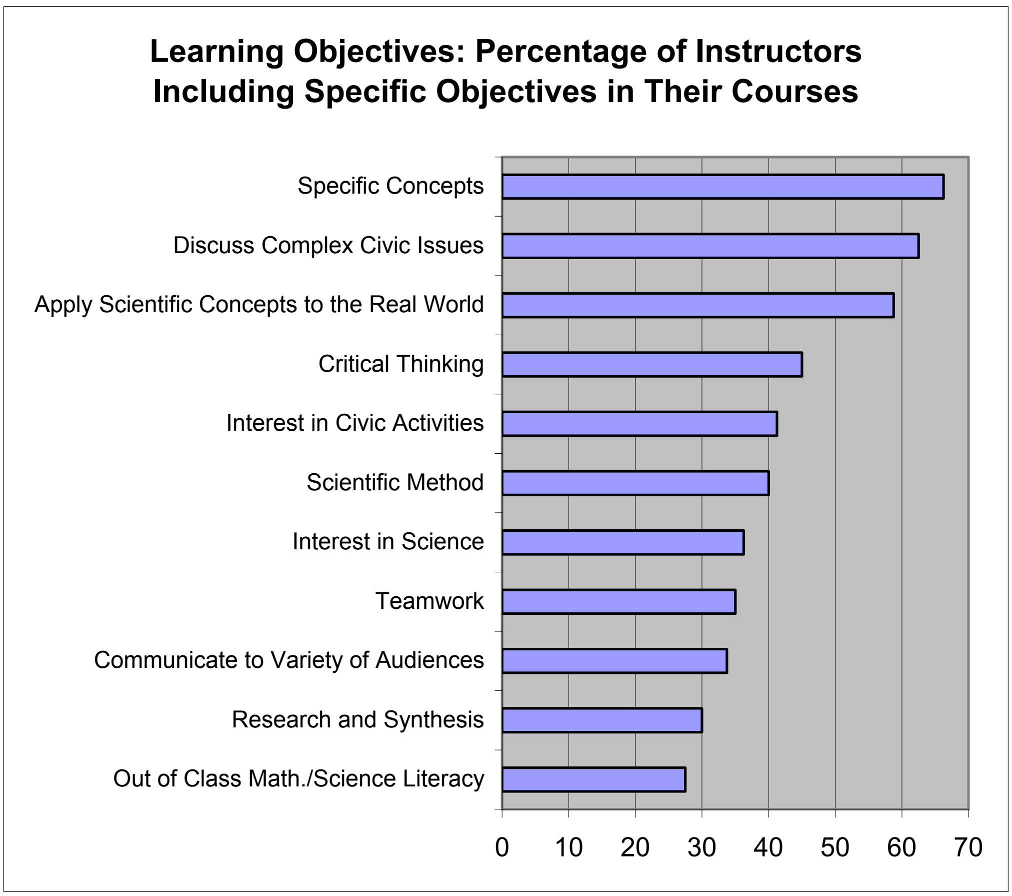
Survey courses on general science and social topics/ current issues.

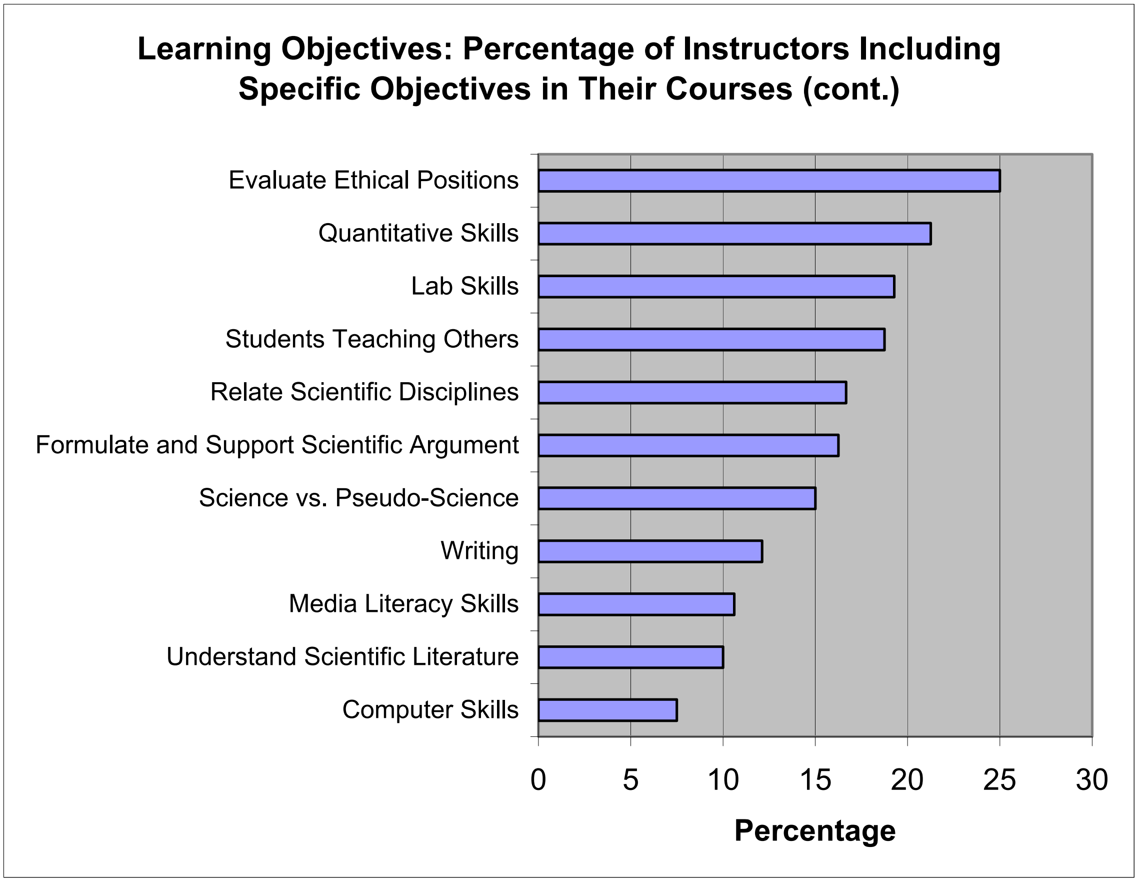
Survey courses were more general and often explicitly examined the intersection of science and society through current events. These courses were sometimes (but by no means mostly) science courses that were already taught before faculty attended SSI, then revamped to become SENCER courses. *Computer Ethics* (Bynum) , a SENCER model course, focused on current societal issues in computer science. *Human Genetics* (Finer) engaged students in discussions on a range of ethical and civic questions related to genetics. In *Chance* (Shah), students were asked to think critically about topics such as polling and voting. Courses in this category vary in their integration of civic and social content. When courses were revamped from existing courses, they tended to add civic material in a more modular way with exercises or discussion of civic content added on as multi-week exercises or as readings.

What types of learning objectives, instructional techniques, assessment and perceived outcomes are described by instructors?

Instructors were asked to identify five of their top learning objectives for their courses. *Learning science content* (66%), *discussing complex civic issues* (63%), *applying scientific concepts to the real world* (59%), and *critical thinking* (45%) were the most frequently cited objectives. (See figure 3 & 4)

Figures 3 & 4: Percentage of instructors including specific learning objectives in their courses.





Instructional methods used in SENCER courses varied widely. Some methods such as *field data gathering* (48%) and *guest speakers* (46%) were more common in case-based courses. The most common instructional activities included *lecture* (all instructors), *group discussion* (83%), and *student presentations* (66%). Common assessment methods included *written assignments* (73%), *projects* (68%), *presentations* (52%) and *research papers* (48%). *Multiple-choice tests* were used by 58% of the instructors. (See figures 5 & 6)

Figure 5: Percentage of instructors using instructional methods

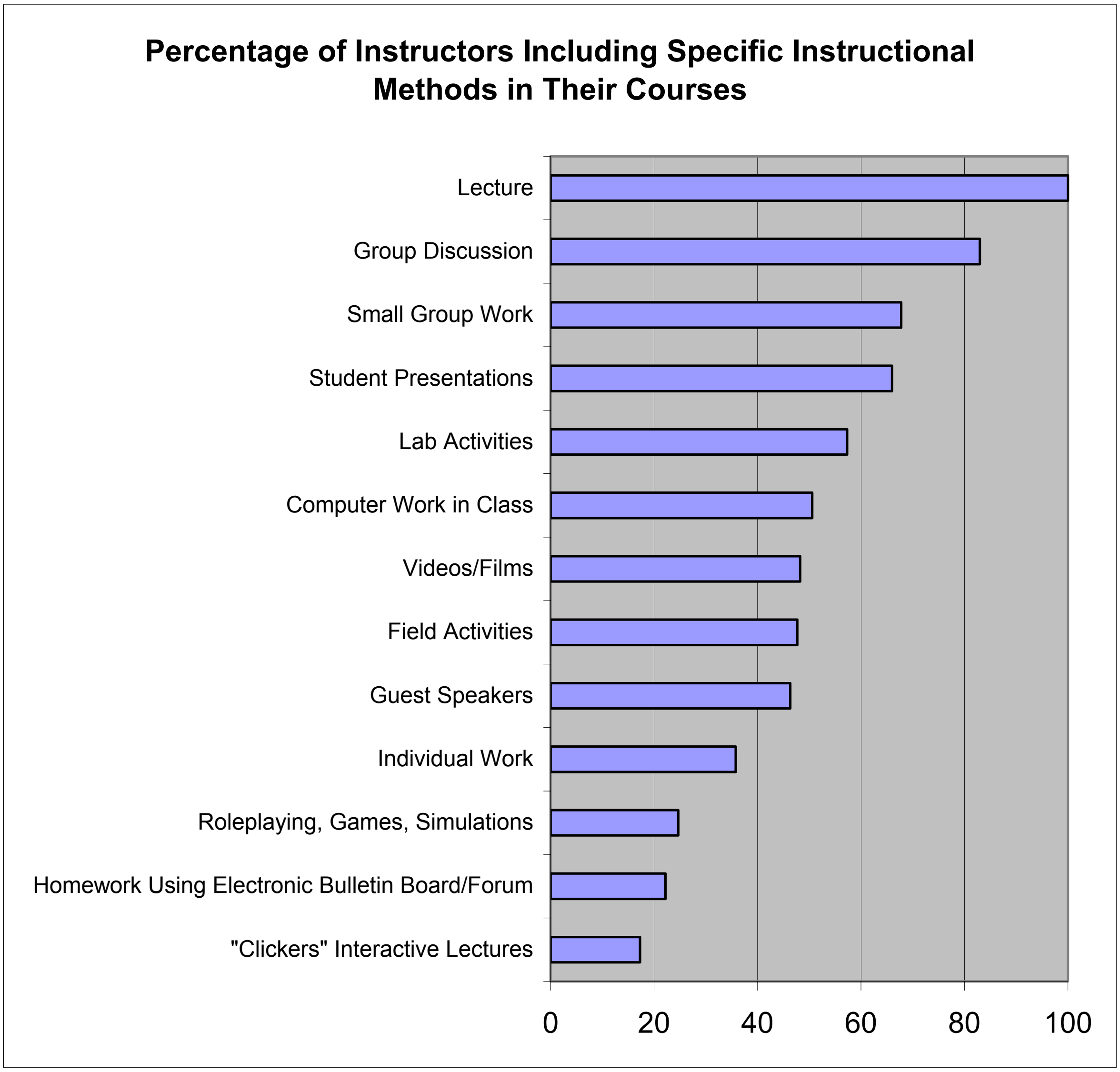
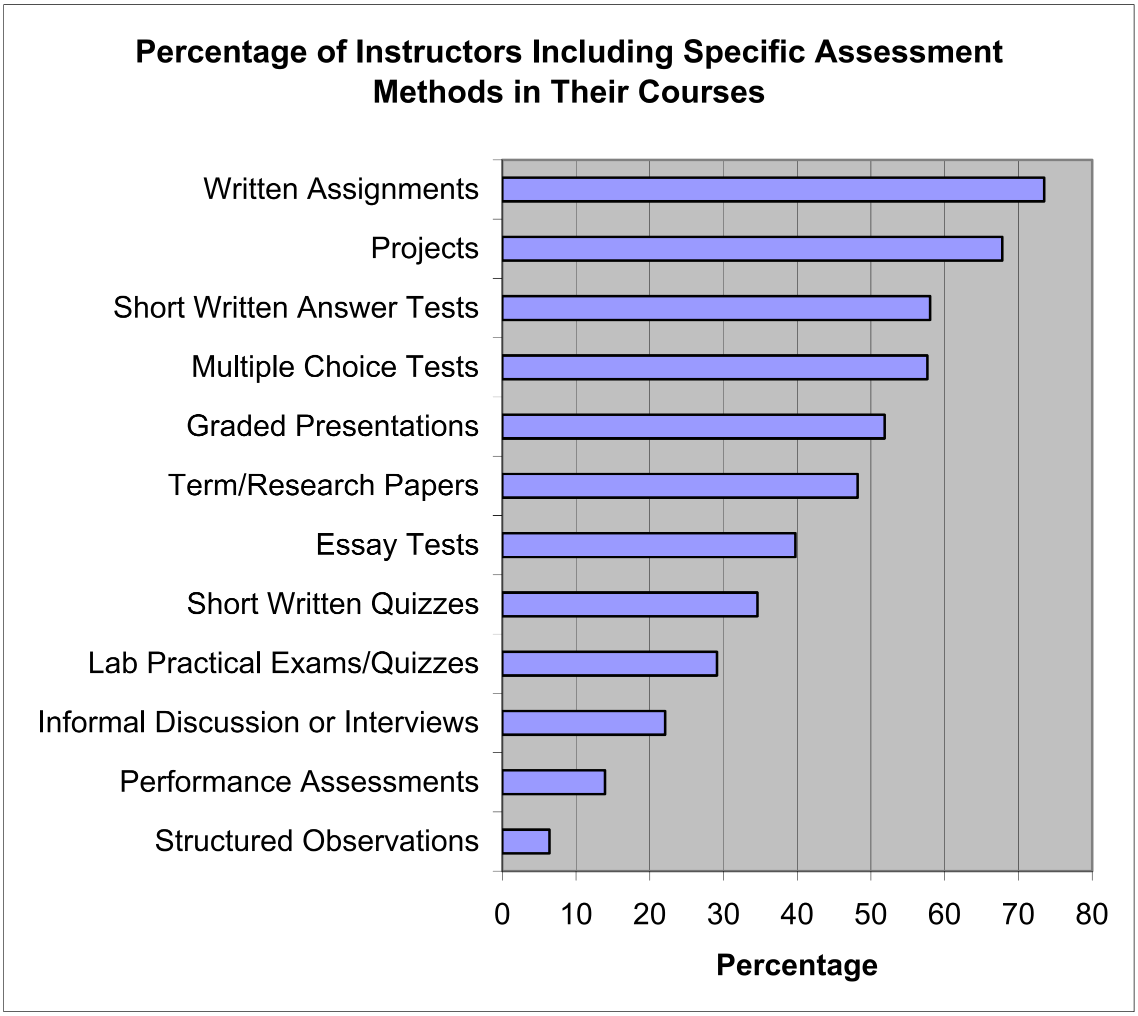


Figure 6: Percentage of instructors using assessment methods



Instructor responses about instructional and assessment methods were scaled[vi] to learn what groups or clusters of methods were typically used by faculty. Instructors using only a few instructional and assessment methods tended to use lecture, small group work, multiple choice and short written answer tests. When new methods were added, projects, field activities and graded presentations were used. Videos, films and technology applications such as electronic discussion boards and class communication systems ("clickers") were least likely to be incorporated. Instructors in the second group were more likely to frame their courses with a case-based approach. Figure 7 shows the pattern of how instructional techniques were added by groups.

---- figure 7 --- (see page 75)

Perceived Outcomes

We asked SENCER faculty what they thought their students gained from taking a SENCER course. I*ncreased student engagement* (77%), *increased awareness of relationships between science and public policy* (56%), *increased learning about science outside of class* (66%) and *increased confidence in science literacy skills* (54%) were the most frequent outcomes. Thirty-nine (39%) percent cited *better academic outcomes* as a perceived student outcome from the SENCER approach. When asked what evidence instructors used as the basis for their perceptions, answers ranged from observations of student behavior (i.e., greater participation in course discussions), conversations with students, responses to surveys such as the SALG and other instruments, student work (i.e., projects, papers and exercises), as well as grades and test scores. Instructors also reported changes in areas such as personal lifestyle (i.e., changed diet, recycling), and greater participation in civic activities. Other evidence included less attrition from courses and more students taking continuing science courses in the future (See Table 1).

Table 1 Percentage of instructors identifying specific outcomes

Outcome	%
More Student Engagement/Participation	77
Increased Awareness of Science/Technology	69
Interest in Learning About Science Outside of Class	66
Increased Awareness of Relationships Between Public Policy and Science	56
Increased Confidence in Science Literacy	54
Increased Confidence in General Science Skills	49
Increased Critical Thinking	49
Greater Interest in Civic Issues	47
Greater Interest in Science	47
Increased Communication Skills	43
Better Academic Performance	39
Greater Likelihood to Participate in Civic Activities	29
Other	28
More Interest in Related Disciplines	19
More Interest in Continuing to Study Science	14
Increased Laboratory Skills	14
More Interest in Scientific Careers	9

What types of service learning occur in SENCER courses?

Thirty-three (33%) percent of instructors reported some form of service learning, political involvement or community outreach as a component of their courses. In some cases activities were considered extra credit, but in many courses service-learning activities were required. Examples of involvement included building community gardens, writing letters to the editor about civic issues, attending public hearings, gathering data on environmental questions, volunteering in the community with organizations working with HIV/AIDS, interviewing community leaders and activists, making presentations on local water quality to environmental groups, and surveying community members on scientific/civic issues.

How do content, instructional methods and service learning relate to each other?

We also examined how content, instructional methods and service learning related to each other. The first comparison compared learning objectives, instructional methods, assessment and perceived outcomes in case-based and survey courses.

The two categories of case-based/survey and service learning/no service learning were significantly associated with each other with service learning much more likely to occur in case-based courses.[vii]

For learning objectives, we found larger differences[viii] favoring survey courses over case-based courses for *learning scientific method*, *encouraging interest in science* and *communicating to a variety of audiences*. Objectives favoring case-based courses included *relating scientific disciplines, research and synthesis* and *discussing complex civic issues*.

When instructional methods were compared, case-based courses tended to include more *field activities*, *guest speakers* and *student presentations.* Assessment methods favoring survey courses included *multiple-choice tests* while case-based courses favored *projects* and *essay tests*. The perceived outcomes of *increased critical thinking* and *increased awareness of relationships between public policy and science* were identified more frequently for case-based courses.

When we compared courses with a service learning/community project component with those without service learning, the learning objectives of *applying scientific concepts to the real world, scientific method, out of class math./science literacy, and communicating to a variety of audiences* were identified in courses without service learning more than those with a service learning component. The course objective *evaluating ethical positions* was more frequently identified in service learning courses.

The instructional methods of *guest speakers, student presentations, field activities* and *videos/films* were also used more often in courses with service learning. *Short written*

quizzes and *multiple choice tests* were featured in non-service learning courses while *project-based assessments* were featured in service-learning courses.
The outcomes of *greater likelihood to participate in civic activities, better academic performance, increased communication skills,* and *more interest in scientific careers* were identified more frequently as perceived outcomes in service learning courses.

The comparison is summarized below in tables 2 & 3

Table 2: Learning objectives, instruction, assessment and perceived outcomes for case-based and survey courses.

Area	**Survey**	**Case-based**
Learning Objectives	Scientific method Encouraging interest in science Communicating to a variety of audiences	Relating scientific disciplines Research and synthesis Discussing civic issues
Instructional Methods		Field activities Guest speakers Student presentations
Assessment	Multiple choice tests	Projects Essay tests
Perceived Outcomes		Increased critical thinking Increased awareness of relations between public policy and science

Note: Areas only listed if significantly greater for case-based or survey courses.

Table 3: Learning Objectives, instruction assessment and perceived outcomes in service learning and non-service learning courses.

Area	**Service Learning**	**Non-service learning**
Learning Objectives	Evaluating ethical positions	Applying scientific concepts to real world Out of class math/science literacy Communicating to a variety of audiences
Instructional Methods	Guest speakers Student presentations Field activities Videos/films	
Assessment	Projects	Short written quizzes Multiple choice tests
Perceived Outcomes	Greater likelihood to participate in civic activities Better academic performance Increased communication skills	

Note: Areas only listed if significantly greater for case-based or survey courses.

2. How do SENCER instructors perceive the SENCER program & what were their recommendations for improvement? What implementation facilitators and obstacles are present for instructors?

Faculty assessments of SENCER provided valuable feedback for program development. Likewise, SENCER faculty were an important source of information about what helped or hindered implementation of new curricula. With surveys and interviews we asked faculty for suggestions on improving SENCER program activities, and solicited descriptions of common implementation facilitators and obstacles.

Overall, faculty provided very positive general assessments of SENCER. Some key findings supporting the effectiveness of the SENCER approach include:

- Support from the SENCER organization (63%) was one of the most frequently cited factors that helped in developing and sustaining a SENCER course.

- Ninety-two percent of instructors believed their courses would be continued in the future.

- Eighty percent considered their course part of the permanent curriculum at their institution.

- Fifty-six percent (56%) said that others in their department teach different sections of their SENCER courses, suggesting that the SENCER approach is spreading and being sustained in departments.

- Seventy-three percent said they maintained contact with other SENCER instructors and 75% said they had logged on to the SENCER website in the past year.

What were instructor recommendations for improving the SENCER program?

<u>Survey Data</u>

Two questions on the faculty survey asked instructors about SENCER program activities, and interviews conducted at SSI with SENCER alumni also included questions about program activities.

When instructors were asked "*What, if anything, can the SENCER organization do to help you sustain your SENCER course?*" the most frequent answer was *continuing present activities* (33%). Other recommendations were *more national outreach* (13%)

and *promoting networking with other instructors* (16%). Examples of responses are presented in table 4.

Table 4: Responses to question: *What, if anything, can the SENCER organization do to help you sustain your SENCER course?"*

Recommendation	**%**	**Example of Response**
Continue present activities	33%	*Continue with what they are doing--it has been quite helpful. I have gained a huge amount from the conferences, especially.*
Help with NSF proposals/ Help get funding	8%	*Encourage NSF to support with small grant support for buyout to hire adjunct (~10K plus full overhead)*
Direct help at institutional level	10%	*Bringing guests speakers to campus to speak to the faculty would be a tremendous asset.*
Continue outreach at national level	13%	*Continue national exposure to validate scholarship of teaching and learning.*
Promoting networking with other instructors in local area	16%	*I have been to SENCER for two years and am well grounded in the "introductory" philosophy regarding the need for a SENCER approach. I need to present ideas and listen to ideas from the alumni, meaning persons who have presented a SENCER course and have tried several approaches. I need to know what works and what doesn't work in various settings, and I believe I will only get this through working with those who have been involved. I will then be better able to present the SENCER idea to my colleagues, and to those new to the SENCER meetings held each August.*
Direct training for designing a SENCER course	7%	*Offer workshops locally for faculty on HOW to institute a SENCER course.*
Publish more models/ other publications	6%	*Publish new models for fresh ideas*
Other	6%	*Encourage more math SENCER courses*

Table 5: Responses to: *What, if anything, could be improved about the way in which SENCER carries out its program activities?*

Promote networking with other instructors in local area/More regional conferences	40%	*Better communicate the availability of SENCER faculty for consultation and sharing of successes beyond the newsletter.*
No suggestions for improvement/ SENCER doing great job	31%	*I think that SENCER is doing excellent work through its summer institute (and its structure), backgrounders.*
Direct help in course design	14%	*Perhaps more time for demonstration or providing guidance on management or organization of specific science / civic focuses.*
Changes to SSI	8%	*Review of presenters should allow you to eliminate some. Some people are part of your "core" only because they've been attending for years. Seniority does not always equal quality.*
Other	9%	

Interview Data: Suggestions for Improvement

A core group of SENCER alumni were interviewed at 2004 and 2005 SENCER Summer Institutes. Interview data provides a more detailed picture of faculty assessments of SENCER program activities, and ideas for improvement.

Overall goals of the SENCER organization

Several SENCER instructors interviewed at the summer institute also stated that they felt that the overall goals of the SENCER organization could be better defined. The SENCER instructors that cited this concern expressed a desire for more clear direction from the SENCER organization; for example, more concrete curricula and exercises for dissemination purposes and more clear direction of how to link science and civic engagement. SENCER instructors acknowledged that broad, open definitions can be an advantage, yet also expressed a desire for more concrete definitions and resources from the SENCER organization. The following quotes express confusion over the dissemination of SENCER and the definition of civic engagement.

> Quote #1 *... I don't really understand the goals of SENCER. I mean, as a dissemination project, I don't know what they're disseminating other than an idea. And that idea is to, you know, get more civic engagement in the classroom, which is a GREAT idea, but, I don't know what they're disseminating.*
>
> Quote #2: *I think, there are two things that I have heard from the participants in all three years. One is a clearer definition of civic engagements. And I'm not sure if that is something that SENCER organizers can do, because I think that they've done a stellar job of making that concept open to interpretation for each individual faculty member within the restrictions or confines of their own course and department and institution, but I think it's still something that people find hard to believe that it could be a liberally interpreted concept. So I think that's something that eludes a strong foundation or capture of this is how we need to say, "link to civic engagement." People want to be told how - not to be told however you want.*

Several SENCER instructors reported personal or second-hand reports of confusion over the dissemination of the SENCER program and program definitions such as "civic engagement."

SENCER alumni also held different notions of what SENCER *should* be doing and how it might expand its mission. For example, SENCER alumni thought that SENCER should focus more on learning communities, more on experiential education, expand its mission to science majors, expand its mission to the dissemination of curricular materials, and provide more financial resources for SENCER teams.

Role of cluster coordinators

SENCER alumni interviewed during the summer sessions said that the role of the cluster coordinator could be better defined. Some of these SENCER instructors were cluster coordinators and/or homeroom leaders, yet felt unsatisfied with the role and wanted clusters to be more effective. For example, one cluster coordinator expressed dissatisfaction with role and wished that the "cluster could do more." The following quotes provide more detail as to the perception of some of the cluster coordinators that the role is vaguely defined. One alumnus commented:

> <u>Quote #1</u>*: And it was interesting that ___________'s discussion on her model was actually very popular and a lot of my homeroom people had been to that, and she had a lot of good things to say. And I said, "Well, are you going to be part of her cluster?" And they said, "Well her cluster was really kind of big, I'll probably just get in contact with her." And so they don't really have a concept of the cluster as beneficial. So I'm not sure whether it's the way that the clusters are marketed, or the fact that the reception maybe wasn't a good time to try to gather people in clusters.*

Another added:

> *As cluster coordinator [the role] is even more vague. You're supposed to magically be able to keep these people who join your cluster active. And actually people from two years ago they're hoping that we can keep active, but they don't, they have $2500, so you can't really organize a meeting. You can send out enough e-mails, but no one responds to my e-mails when I do send them. I don't know what the cluster is supposed to do…there doesn't seem to be a goal for the clusters.*

Cluster coordinators expressed a desire to "do more" in their role as cluster coordinator and perceived the role of cluster coordinator and purpose of the clusters as unclear.

What helped implementation of SENCER courses?

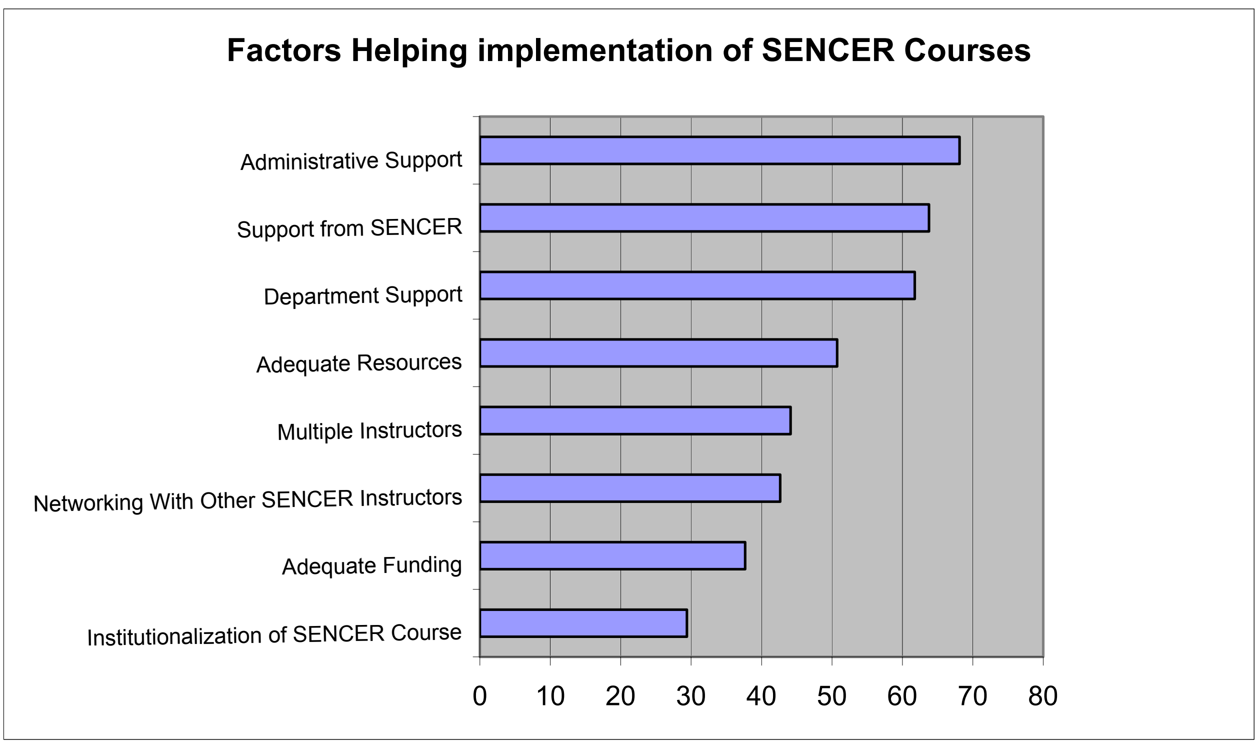
Any educational reform effort faces implementation facilitators and challenges. In higher education these can be especially critical to the success of new approaches to teaching and learning.

Survey data about implementation facilitators

While a number of factors were identified as helping program implementation, support from the SENCER organization (63%) was one of the most frequently cited factors for developing and sustaining a SENCER course.

Other facilitators included administrative (68%) and departmental support (61%). The ability to team-teach courses (45%) and having adequate resources from the institution (50%) were also cited as helping support implementation. Figure 8 shows the factors identified by instructors as helping implementation of courses.

Figure 8: Factors helping implementation of SENCER courses



When instructors were asked "*What helped you the most in implementing your SENCER course,*" 29% identified support from SENCER as most helpful through experiences at SSI and reading SENCER models. Administrative and institutional support were identified by 39% of instructors as most helpful; a number of instructors said that they would not be able to implement a SENCER course without the help of their deans. Others identified adequate funding (15%) and team teaching (17%) as most helpful.

Interview data about implementation facilitators

We learned a great deal about what helps the implementation of SENCER courses through interviews with SENCER alumni.

Help from the SENCER organization

Approximately three-quarters of the SENCER alumni mentioned that the SENCER organization had been helpful in the planning and implementation of their SENCER course. Most of these instructors found the outside recognition provided by SENCER to be most helpful to their efforts. Recognition was provided by the SENCER organization in two ways: outside recognition to the campus in the professional community of higher education science educators, and personal recognition of the achievements of the SENCER instructor. Instructors reported that the SENCER organization had made "national inroads" and therefore their institution had received recognition through its involvement with SENCER.

> *It's a nice thing is to be able to point to a national group and say, "Look, this isn't just some hair-brained scheme from a couple of people sitting around a table over here. This really is something that people nation-wide are giving credence to, that you need to be doing this."*

Instructors also reported that they had received personal recognition from the SENCER organization through letters of support for grants or to campus administrators. Several SENCER instructors also mentioned that a campus visit by SENCER personnel had been helpful in educating colleagues and administrators about the SENCER program.

> Quote #1: *They are willing to write letters of support about what we accomplished last year at the institute. I think that was very helpful. And that went to our administrators. One of the things that is another SENCER outcome, I guess, are all the different conferences that SENCER has facilitated my involvement in to talk about what we're doing at other, at other meetings.*

> Quote #2: *…SENCER has helped me from everything from writing letters to the Dean saying "look at your boy here, he's doing a good job." You know, that's a big help to me at a small institution to get that kind of recognition.*

SENCER also supported instructors' professional development in using innovative pedagogy.

> Quote # 1*: SENCER has definitely encouraged me to broaden my teaching style, absolutely. It's given me training, education, support in the literature, support in*

colleagues, to justify trying new ways of teaching. Absolutely, it's been a huge professional development for me.

Quote # 2: *It has been probably the best professional development I've had in a long time. And as far as bringing together appropriate colleagues, and the mixture of pedagogy and theory, and inspiration for courses.*

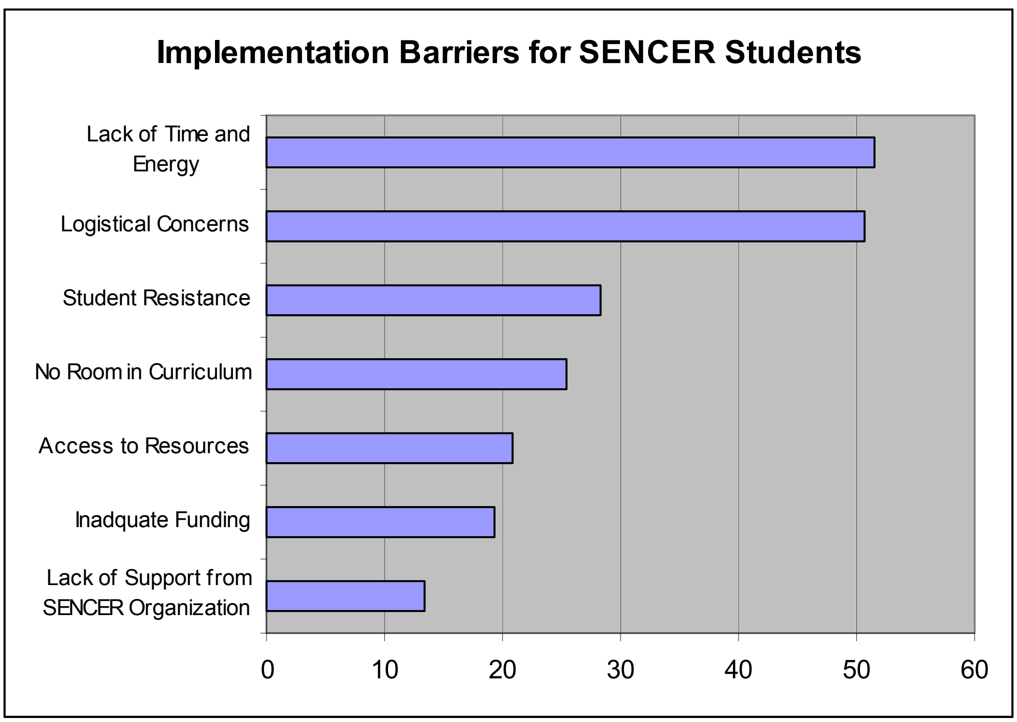
What implementation barriers were perceived by instructors?

Survey data about implementation barriers

While instructors identified numerous barriers to implementation, it should be noted that most were able to overcome obstacles and sustain their courses. Ninety-two percent of instructors believed their courses would be continued in the future, and 80% considered their course part of the permanent curriculum at their institution.

The most common implementation barriers identified by SENCER instructors were lack of time and energy (53%) and logistical concerns (51%). Logistical concerns identified through interviews included scheduling, course availability, and the inability of the institution to support team teaching or field activities. Student resistance (28%) and lack of flexibility in the curriculum (25%) were the next most common barriers. Problems identified by faculty related to students were lack of interest by students in specific course topics, and resistance to innovative instructional techniques such as working in groups. Fewer instructors said that access to resources (21%), funding (19%) or lack of support from SENCER (15%) were barriers for implementation. (See figure 10).

Figure 9: Implementation barriers for SENCER instructors



When instructors were asked to identify the *greatest* barrier to implementing a SENCER course, 34% identified lack of time and energy, often citing the great deal of work involved in designing or retooling courses. Seventeen percent identified colleagues as the greatest barrier, describing peers who were resistant to teaching a different section of the same course, who felt reform courses were not rigorous enough, or who were wary of their departments' support of innovative pedagogy. Seventeen percent also identified lack of administrative support as a barrier to implementation with various logistical concerns such as gaining credit for the course, or actively resistant deans identified as specific barriers. Student resistance to new types of instruction was also identified by 10% of the instructors; another 10% said that curricular barriers such as inability in new courses to teach required content were their greatest barrier to implementation.

Interview data about implementation barriers

Interviews provided more detail on many of the implementation barriers facing faculty members attempting to implement SENCER courses. Barriers included institutional factors such as resistance from colleagues and lack of financial resources, as well as more individual barriers such as lack of time. While faculty encountered numerous barriers, overall most experienced remarkable success in implementing and sustaining their SENCER courses.

Resistance from colleagues

Close to three-quarters of the SENCER alumni interviewed encountered some type of resistance from colleagues. The most common complaint is that faculty colleagues did not think the SENCER instructors' courses were rigorous enough. Some SENCER alumni reported encountering resistance from colleagues even before their involvement with the SENCER project. While a few SENCER alumni still struggle for acceptance within their departments, most felt they have overcome this barrier. SENCER alumni have been able to overcome faculty resistance through various means such as securing external funding that increased their status within the department and served as external validation of alternative teaching techniques or research agenda. Other instructors shared syllabi and course materials with colleagues to demonstrate the rigor of their course. The following quote illustrates the way that external funding helped an instructor to gain legitimacy from colleagues.

> *I've had a long track record of being sort of a marginalized member of my department…I've been accused of not really doing chemistry. They were worried about whether it was fundable or not. At one point in the past couple years I was the highest extramurally funded person on campus. My colleagues have decided [that what I do] is definitely fundable, and about half of them are now doing similar sorts of projects.*

Another instructor asserted that he is using external professional organizations to gain legitimacy from colleagues.

> *There may be some people in the faculty who aren't sold that there should be any need to change. But I think no matter what we did, they would always feel that. And so what I've tried to point on - some very pointedly, some in dramatic, diplomatically - that you know, your opinion's in the*

> *significant minority. Contrary to institutions you respect. The National Science Foundation, American Association of Advancement of Science, all your own professional organizations, with physics, or wherever, I mean all are doing this.*

While most SENCER alumni had encountered faculty resistance, they have found that demonstrating rigor, securing external funding, and association with professional organizations engaged in reform activities have helped to counter this potential barrier. Similar findings about how external funding and national organizational outreach legitimate reform efforts were explored in a research paper by University of Wisconsin researchers.[ix]

Student resistance

Approximately half of SENCER alumni reported experiencing student resistance to reformed teaching methods. Instructors reported that students are resistant to taking initiative for their own learning, to group work and hands-on activities, and the focus on conceptual learning over facts and memorization. Again, successful SENCER instructors have been able to counter student resistance. Most instructors reported that students gradually warmed to active learning as the semester progresses. Through self-assessments and anecdotal evidence, students voiced less resistance to active learning over the course of the semester. The following quote illustrates a common source of student resistance, the emphasis on active learning:

> *So I put them [students] in those kinds of [real-life] situations. They HATE me for doing that kind of stuff. Because you know, it's something they're not used to having to do this. So it's sort of funny, I can be downgraded…they can complain, "the teacher didn't really teach me. The teacher just turned me loose." And that's true. And what they don't understand is that the teacher didn't spoon feed them. And they've been…all of their life they've been spoon fed. And suddenly you put them in situations where they're trying to get it for themselves and they're saying: "Well wait a minute, I paid money…you're supposed to tell me what to, what I'm supposed to know. What do I need to know for the test?"*

This finding supports earlier research conducted by Seymour with the Chemlinks and ModularChem projects that showed students commonly resist pedagogy that asks them to take an active role and responsibility for their learning.[x] Generally, resistance is linked to initial panic about the teacher taking away their "formula" for getting good grades. There is additionally a sense that the teacher is breaking an implicit contract by not lecturing and insisting that the students learn in a different way than they are used to.

Lack of time

About half of the SENCER alumni interviewed cited lack of time as a potential barrier to course implementation and sustainability. Instructors reported that it is difficult to teach a SENCER course, be associated with SENCER, and complete their own scholarship.

> Quote #1: *I think that, the reality is it can become quite a pyramid scheme, in a way. You know, like every year you, you have more to do, and I think that the longer that you're associated as a SENCER faculty member, the reality is we can't really maintain that increasing level of work and get our own work done.*
>
> Quote #2: *Well, my own personal barrier is just lots of other, doing lots of other things now. So, ultimately, I would like to have other people involved in teaching the course and this kind of thing. So I think part of it is just demand on time.*

SENCER instructors that cited lack of time as a concern were more likely to teach the course alone and to not have any colleagues in the department who also teach a section of the course. They are often the most involved SENCER team member as well. All of these factors place more of a time burden on these SENCER alumni.

Lack of Financial Resources

A quarter of SENCER alumni interviewed cited financial resources as a potential barrier to course sustainability, a finding consonant with approximately 20% of those answering the survey. Many of the SENCER courses hinge on extra resources such as summer funding for planning or development, teaching assistants, field trips, supplemental supplies or materials, and/or course release time. SENCER alumni have been successful in securing funding through grants or supportive administrators, however, financial resources are still a source of concern for most of the SENCER alumni. The following quotes summarize the concerns of instructors regarding inadequate budgets and additional needs within SENCER courses:

> Quote # 1: *We actually have the board approve a budget for the learning communities for next year. It's probably not quite enough, but it was, you know, I'm sure, very substantial in their mind.*
>
> Quote #2: *One barrier is…probably is, and I haven't explored this, but one barrier is probably just resources. I teach on a shoestring. I literally go to Wal-Mart …so I don't spend much money.*

Bureaucracy

By including administrative support in SENCER teams, faculty have successfully sustained their courses. However, institutional bureaucracy has also served as a barrier to sustainability, particularly on larger campuses. For example, campus committees, degree requirements, and the process of institutionalizing a course at a larger university can be slow and time-consuming. SENCER instructors from smaller colleges were less likely to report that bureaucracy was a barrier to course sustainability. A SENCER instructor expressed the cumbersome nature of university bureaucracies:

> *Ideally, we would like to offer the course, or co-list it, in biology, in psychology and as something for the educators, so we'd like to see it co-listed in all of the departments, because I think in the eyes of the scientist, if you will, that makes it more valid. But we're not going to try that initially because again curriculum committees at large universities are notoriously slow, and cumbersome and will keep coming back to us with questions, and they're going to want lots of detail regarding how it fits into the curriculum or the degree requirements.*

3. Across all courses, what activities "help students learn," and are these activities consonant with the SENCER approach?

Students responding to the SENCER-SALG rated course activities in SENCER courses for what "helped them learn." This part of the survey was also used by SENCER faculty to fine-tune their course design. Questions cover class focus, class activities, graded activities and assignments, and external class activities.

Do students rate civic/social learning activities highly in comparison with more traditional activities?

Student responses to the SENCER-SALG were aggregated across all courses in the database.[xi] Aggregate responses provide a broad picture of how students in SENCER courses rank activities and other course elements.

The SENCER- SALG (post version) first asks students to rate how much specific course focus, activities, graded activities and external course activities "helped my learning." For the original SALG, feedback from this section informs instructors about how course redesigns are perceived by students. For the SENCER-SALG, these items also provide feedback for instructors, but are also used to assess relative ratings of students in SENCER courses.

Ratings are somewhat contradictory; on one hand, traditional aspects of undergraduate education such as *focus on learning science facts* (3.69), and learning activities such as *lecture* (3.79)*, receiving in-class review* (3.64), and *individual studying* (3.78) were rated the highest by students. However, other areas more consonant with SENCER such as *focus on addressing real world issues* (3.61), and the *interplay between science and civic issues (3.45)* also received high ratings. Some "innovative" instructional methods[xii] such as *group work* (3.06), *participating in group projects* (2.9) and *preparing for oral presentations* (2.9) received lower relative ratings. Some of the ratings for projects, group work and presentations were much higher in courses without implementation problems (see section 6 for this comparison).

Table 6 Ranked average ratings on a five-point scale.[xiii]

How much did each of the following help your learning?"

Focus on….	Average
Learning scientific facts	3.69
Addressing real world issues	3.61
Gathering data in labs or field	3.53
Interplay between science & civic issues	3.45
Learning how real science is done	3.37
Summarizing scientific results	3.35
Using scientific methods	3.18
Analyzing scientific data	3.14

The class activities:	Average
Lecture	3.79
Lab	3.5
Activities Media	3.4
Discussion	3.37
Computer	3.17
Group work	3.06
Individual work	3.0

Graded activities and assignments:	Average
Receiving in class review before tests	3.64
Receiving feedback on our work	3.26
Completing written assignments	3.22
Participating in group/team projects	2.9
Preparing for oral presentations	2.9

Table 6 Ranked average ratings on a five-point scale (cont.)

External class activities:	Average
Studying individually	3.78
Studying with partner	3.45
Studying with group	3.21
Receiving help from a TA	3.21
Receiving help from instructor outside class	3.13

4. In which areas of the SENCER-SALG do students gain more or less in ratings of skills, interests and activities?

What are the overall results of the SENCER-SALG over five semesters?

The SENCER-SALG contains blocks of items about confidence in science skills, interest in science and civic activities. The items for confidence and interest were administered in pre/post administrations at the beginning and end of each semester.

Overall, gain from pre to post was greater for items asking about *confidence in science literacy activities* followed by *confidence in general science skills. Interest in science literacy activities* showed smaller gains; interest in "*advanced" science activities* showed the smallest gains.

To give some context to pre-post gains, it is useful to look at the numbers of students moving from one rating category to another from pre to post. For example, the gain for the item "*I am confident I can make an argument using scientific evidence*" which showed a gain of .59 on a five-point scale translates into a one point jump on a five-point rating scale for 33% (n = 1830) of the students, and a two or more point gain for another 20% (n = 1159) of the students. Even the small gains in the "advanced" science activities masked a sizable group of students who show little or no interest in these activities at the beginning of the course, but then report being highly or extremely interested in the activities at the end of the course. Ten percent moved from the lower group to the higher group for the item "*I am interested in taking additional science courses after this one,"* while five to six percent of students made this shift for other advanced science items such as interest in majoring in science related subject and interest in attending graduate school in a science-related area.

Gain from pre to post varied with larger gains in science literacy items such as *I am confident I can make an argument using scientific evidence* (.59) and *I am confident I can think critically about scientific readings in the media* (.55). Science process skills also demonstrated relatively larger gains such as those shown on items such as *I am confident I can give a presentation about a science topic to a class* (.49) and *I am confident I can organize a systematic search for relevant data to answer question* (.47).

Smaller gains were found for items rating confidence in understanding tables and graphs, and in gathering data in lab. 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 scientist or entering graduate school in science. (See tables 7 – 10).

Across most of the activities, roughly 20% of students who said they had never engaged in specific civic activities such as writing letters to the editor or attending public meetings before the course said they were more likely to engage in these activities in the future. Items about civic activities were not directly comparable from pre to post because of their different scales. Pre items asked for a report on participation in activities over the past year, while the post asked for assessments of students' likelihood of participating in civic activities in the future. A small minority of students engage in many of the civic activities asked about in the survey. To examine if any changes were made in students' attitudes, the responses of students who had "never" engaged in specific activities were examined to learn if they would engage in the activity in the future. (See tables 11 -12)

Table 7: Item averages for pre and post (Confidence in science literacy)

Item	Pre (mean)	Post (mean)	Gain
I am confident I can discuss scientific concepts with friends or family	2.96	3.45	0.50
I am confident I can think critically about scientific readings in the media	2.93	3.48	0.55
I am confident I can determine what is and isn't valid scientific evidence in the media	2.90	3.40	0.50
I am confident I can make an argument using scientific evidence	2.81	3.40	0.59
I am confident I can determine the difference between science and pseudo-science	2.33	3.12	0.79
Confidence in Science Literacy Composite	**13.97**	**16.89**	**2.92 -3.1** **.72** [a]

[a] Range includes estimate for all students taking pre and post, second number is only students who took both pre and post. Lower number is standardized gain with gain/standard deviation for gain.

Table 8: Item averages for pre and post (Confidence in general science skills)

Item	Pre (mean)	Post (mean)	Gain
I am confident I can interpret tables and graphs	3.60	3.70	0.10
I am confident I can understand math/stat formulas found in texts	2.86	3.09	0.23
I am confident I can find scientific journal articles using library/internet databases	3.14	3.61	0.47
I am confident I can extract main points from a scientific article and make summary	3.15	3.59	0.44
I am confident I can give a presentation about a science topic to a class	2.97	3.46	0.49
I am confident I can obtain scientific data in a lab or field setting	2.83	3.08	0.25
I am confident I understand how scientific research is carried out	3.05	3.34	0.29
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence	2.87	3.29	0.42
I am confident I can organize a systematic search for relevant data to answer question	2.73	3.20	0.47
I am confident I can write reports using scientific data as evidence	2.94	3.39	0.45
I am confident I can work with others collaboratively on scientific project	2.78	3.57	0.79
I am confident I can apply scientific information to social concerns	3.23	3.53	0.29
Confidence in General Science Skills Composite	**30.21**	**33.87**	**3.66 – 3.93 .49**

Note: Composite does not include "I am confident I can apply scientific information to social concerns"

Table 9: Item averages for pre and post (Interest in science literacy)

Item	Pre (mean)	Post (mean)	Gain
I am interested in discussing science with family or friends	2.59	2.97	0.38
I am interested in reading about science and relation to civic issues	2.75	2.98	0.23
I am interested in reading articles about science	2.59	2.87	0.28
Interest in Science Composite	**7.93**	**8.82**	**.85-.89 .32**

Table 10: Item averages for pre and post (Interest in "Advanced" science)

Item	Pre (mean)	Post (mean)	Gain
I am interested in taking additional science courses after this one	2.53	2.69	0.15
I am interested in majoring in a science related field	2.21	2.22	0.01
I am interested in exploring career opportunities in science	2.22	2.24	0.03
I am interested in joining a science club or organization	1.70	1.83	0.13
I am interested in attending grad school in a science related field	1.92	1.95	0.03
I am interested in teaching science	1.49	1.62	0.13
Advanced Science Interest Composite	**12.03**	**12.48**	**.42- .45 .08**

Table 11: Percentage of students engaging in civic activities

Item	Percent engaging in activity at least once during last year
How often have you discussed a science related issue informally (past year)	94%
How often have you discussed a civic or political issue informally (past year)	95%
How often do you read a science-related magazine not required by class (past year)	69%
How often have you written a letter to a public official about a political issue (past year)	23%
How often have you talked with a public official about a civic or science-related issue (past year)	17%
How often have you debated or offered public comment on a scientific issue (past year)	27%
How often have you debated or offered public comment on a civic or political issue (past year)	38%
How often have you attended a meeting, rally, or protest about a civic or political issue (past year)	32%
How often have you written a letter to the editor about a civic or political issue (past year)	9%
How often have your written a letter about a science related issue (past year)	3%

Table 12: Percentage of students who answered never on pre who said agree of strongly agree on post

Item	Percent answering "never" on pre who said agree or strongly agree on post
I am more likely to discuss a science-related issue informally	27%
I am more likely to discuss civic or political issue informally	23%
I am more likely to read a science related magazine not required by class	24%
I am more likely to write a public official about political issue	18%
I am more likely to write a public official about science issue	17%
I am more likely to talk with a public official about science or political issue	17%
I am more likely to debate or offer comment on a scientific issue	22%
I am more likely to debate or offer comment on a political issue	20%
I am more likely to attend a meeting or rally	20%
I am more likely to write a letter to the editor about a civic issue	20%
I am more likely to write a letter to the editor about a science issue	17%

Table 13 Average ratings on post SENCER-SALG for civic engagement items

Item	Mean
I am more likely to discuss a science-related issue informally	3.36
I am more likely to discuss civic or political issue informally	3.30
I am more likely to read a science related magazine not required by class	3.06
I am more likely to write a public official about political issue	2.59
I am more likely to write a public official about science issue	2.51
I am more likely to talk with a public official about science or political issue	2.54
I am more likely to debate or offer comment on a scientific issue	2.66
I am more likely to debate or offer comment on a political issue	2.69
I am more likely to attend a meeting or rally	2.71
I am more likely to write a letter to the editor about a civic issue	2.54
I am more likely to write a letter to the editor about a science issue	2.45
I am interested in participating in an internship with a scientific lab or organization	1.97
I am interested in learning more about other scientific disciplines	2.36
I am interested in volunteering for science-related community service	2.26
I am interested in participating in non-formal science ed at museum or school	2.18
I am more likely to join a science-related civic organization	2.33
I am more likely to participate in a science related civic education	2.42
I am more likely to do an internship at a civic organization	2.50
I am more likely to work as a volunteer for political campaign	2.79
I am more likely to participate in one time civic events	3.58
I am more likely to vote in elections	4.02

5. Do specific demographic groups gain more or less from pre to post on SENCER variables? Who benefits the most from SENCER courses?

How demographic groups respond differently to questions on the SENCER-SALG is important to the overall goals of the SENCER. Traditionally, both women and non-science majors have received less attention than men and science majors in science education. Reform efforts have concentrated on reaching out to these populations.

The demographic breakdown of the sample of student taking the SENCER-SALG is presented in table 14. Demographic categories include gender, major, class standing, and self-reported grade point average (categorical). Compared with national population of university students provided by the National Center for Educational Statistics, women were over-represented in the SENCER sample, while minority students were under-represented.

Do men or women gain more from pre to post on SENCER-SALG items and composite items?

On most SENCER-SALG confidence and interest items, women tend to rate these areas lower on the pre, but then close the gap with men on the post.[xiv] Over all the courses given the survey, women gained significantly more than men on items such as *I am confident I can work with others collaboratively on scientific project* (women gained .27 more than men) and *I am confident I can apply scientific information to social concerns* (women gained .17 more than men). Differences in gain by gender were smaller for many science process skills such as *I am confident I can organize a systematic search for relevant data to answer questions* (.08) *and I am confident I can give a presentation about a science topic to a class (.07).* No significant differences were found for more "advanced" science interest items such as majoring in a science related field or joining a science club.

Putting comparative gains into perspective, for the item *I am confident I can work with others collaboratively on a scientific project*, 66% of the women answering the survey gained one or more point on the five-point rating scale, while 55% of men did the same.

See table 15 for gender differences by item.

Do results differ for science v. non-science majors?

On most SENCER-SALG confidence and interest items, non-science majors tended to rate most items lower on the pre, but then close the gap with science majors on the post. Almost all items from the survey showed significant differences between gains for science and non-science majors. Exceptions were items about understanding tables and graphs, and mathematics and statistics formulas. The largest differences in gain favoring the non-science majors were in confidence and interest in discussing science with family or friends. Only active science majors were included in this analysis (not those planning on becoming majors).

In terms of percentages of gain for each group, a difference in gain for an item such as *I am confident I can discuss scientific concepts with friends or family* (favoring non-majors) translates into 52% of the non-science majors gaining one or more points from pre to post, while 45% of the science majors made this similar gain.

See table 16 for the science major comparison.

Table 14: Demographics of the SENCER-SALG sample

Ethnicity	%	Gender	%	Class Standing	%	GPA	%	Science Major	%
White	81	Male	37	Freshman	40	Below 2.0	2	Science Major	18
African America	6	Female	63	Sophomore	31	2 - 2.5	5	Not a science major	40
Hispanic	5			Junior	15	2.5 - 3.0	18	Undecided at this time	15
Native American	1			Senior	12	3.0-3.5	40	Plan on becoming a science major	14
Asian	5			Other	2	3.5 - 4.0	35	Plan on becoming a major in another area	13
Other	3								

Table 15: Gain and difference in gain for males and females by item

	Pre Survey		**Post Survey**		**Gain**		
	Female	Male	Female	Male	Female gain	Male gain	Difference in gain (F - M)
I am confident I can discuss scientific concepts with friends or family	2.84	3.17	3.42	3.60	0.59	0.43	0.16**
I am confident I can think critically about scientific readings in the media	2.81	3.14	3.44	3.62	0.63	0.48	0.14**
I am confident I can determine what is and isn't valid scientific evidence in the media	2.79	3.09	3.34	3.57	0.55	0.48	0.08
I am confident I can make an argument using scientific evidence	2.66	3.07	3.33	3.58	0.67	0.51	0.16**
I am confident I can determine the difference between science and pseudo-science	2.21	2.55	3.06	3.31	0.85	0.76	0.09*
I am confident I can interpret tables and graphs	3.49	3.79	3.65	3.85	0.16	0.06	0.10*
I am confident I can understand math/stat formulas found in texts	2.71	3.12	2.99	3.31	0.28	0.19	0.09**
I am confident I can find scientific journal articles using library/internet databases	3.15	3.13	3.65	3.61	0.50	0.48	0.02
I am confident I can extract main points from a scientific article and make summary	3.11	3.20	3.59	3.64	0.48	0.43	0.05
I am confident I can give a presentation about a science topic to a class	2.90	3.10	3.43	3.56	0.53	0.46	0.07*
I am confident I can obtain scientific data in a lab or field setting	2.75	2.95	3.04	3.13	0.29	0.17	0.11**
I am confident I understand how scientific research is carried out	3.00	3.14	3.32	3.42	0.32	0.28	0.05
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence	2.78	3.01	3.24	3.41	0.46	0.39	0.06*
I am confident I can organize a systematic search for relevant data to answer questions	2.65	2.87	3.17	3.30	0.51	0.43	0.08*
I am confident I can write reports using scientific data as evidence	2.87	3.07	3.35	3.50	0.48	0.42	0.06
I am confident I can work with others collaboratively	2.68	2.95	3.59	3.58	0.91	0.63	0.28**

Table 15: Gain and difference in gain for males and females by item (cont.)

	Pre Survey		Post Survey		Gain		
	Female	Male	Female	Male	Female gain	Male gain	Difference in gain (F - M)
I am confident I can apply scientific information to social concerns	3.15	3.38	3.52	3.58	0.37	0.20	0.17**
I am interested in discussing science with family or friends	2.55	2.67	3.02	2.97	0.47	0.30	0.17**
I am interested in reading about science and relation to civic issues	2.71	2.84	3.01	3.02	0.31	0.18	0.12**
I am interested in reading articles about science	2.52	2.72	2.86	2.95	0.35	0.23	0.12**
I am interested in taking additional science courses after this one	2.46	2.66	2.68	2.77	0.22	0.11	0.11**
I am interested in majoring in a science related field	2.15	2.34	2.20	2.36	0.05	0.02	0.03
I am interested in exploring career opportunities in science	2.15	2.34	2.22	2.36	0.07	0.02	0.05
I am interested in joining a science club or organization	1.69	1.73	1.81	1.88	0.13	0.15	0.02
I am interested in attending grad school in a science related field	1.87	2.00	1.91	2.07	0.04	0.07	0.03
I am interested in teaching science	1.48	1.50	1.60	1.67	0.12	0.17	0.05*

Table 16: Gain and difference in gain for science majors and non-science majors by item

	Pre		Post		Gain		
	NSM	**SM**	**NSM**	**SM**	**NSM gain**	**SM gain**	**Difference in gain**
I am confident I can discuss scientific concepts with friends or family	2.89	3.31	3.45	3.63	0.56	0.32	0.24**
I am confident I can think critically about scientific readings in the media	2.87	3.24	3.48	3.62	0.61	0.38	0.22**
I am confident I can determine what is and isn't valid scientific evidence in the media	2.85	3.14	3.40	3.55	0.55	0.41	0.15**
I am confident I can make an argument using scientific evidence	2.74	3.14	3.38	3.60	0.64	0.46	0.17**
I am confident I can determine the difference between science and pseudo-science	2.26	2.67	3.11	3.30	0.84	0.63	0.22**
I am confident I can interpret tables and graphs	3.56	3.75	3.69	3.85	0.13	0.10	0.03
I am confident I can understand math/stat formulas found in texts	2.81	3.11	3.04	3.36	0.24	0.25	-0.01
I am confident I can find scientific journal articles using library/internet databases	3.11	3.29	3.61	3.75	0.50	0.46	0.03
I am confident I can extract main points from a scientific article and make summary	3.11	3.31	3.59	3.70	0.48	0.38	0.10*
I am confident I can give a presentation about a science topic to a class	2.93	3.20	3.47	3.55	0.54	0.35	0.19**
I am confident I can obtain scientific data in a lab or field setting	2.76	3.16	3.02	3.34	0.26	0.18	0.08*
I am confident I understand how scientific research is carried out	2.99	3.33	3.32	3.55	0.32	0.23	0.10**
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence	2.82	3.13	3.27	3.46	0.46	0.34	0.12**
I am confident I can organize a systematic search for relevant data to answer question	2.68	2.97	3.19	3.36	0.50	0.39	0.11

Table 16: Gain and difference in gain for science majors and non-science majors by item (cont.)

	Pre		Post		Gain		
	NSM	SM	NSM	SM	NSM gain	SM gain	Difference in gain
I am confident I can write reports using scientific data as evidence	2.89	3.19	3.37	3.56	0.48	0.37	0.11
I am confident I can work with others collaboratively on scientific project	2.72	3.06	3.56	3.72	0.84	0.66	0.18**
I am confident I can apply scientific information to social concerns	3.19	3.46	3.53	3.60	0.34	0.15	0.19**
I am interested in discussing science with family or friends	2.50	3.07	2.94	3.24	0.45	0.18	0.27**
I am interested in reading about science and relation to civic issues	2.67	3.15	2.96	3.24	0.29	0.09	0.20**
I am interested in reading articles about science	2.50	3.05	2.82	3.23	0.32	0.18	0.14**
I am interested in taking additional science courses after this one	2.33	3.56	2.53	3.55	0.20	-0.01	0.21**
I am interested in majoring in a science related field	1.91	3.71	1.96	3.58	0.05	-0.13	0.18**
I am interested in exploring career opportunities in science	1.93	3.63	2.00	3.52	0.07	-0.11	0.18**
I am interested in joining a science club or organization	1.53	2.58	1.67	2.61	0.15	0.04	0.11**
I am interested in attending grad school in a science related field	1.65	3.24	1.73	3.09	0.07	-0.14	0.22**
I am interested in teaching science (pre)	1.39	1.98	1.54	2.02	0.15	0.04	0.11**

Which demographic factors predict gain?

Overall, gender and science major were the most reliable predictors of composite variables from the SENCER-SALG, with being female predicting three of the four variables, and not being a science major predicting two of the four variables. Several ethnic/racial groups showed less gain on the science literacy variable. As GPA went up, gain in science interest went down. Being a senior was also associated with less gain for science literacy and science literacy interest.

We used multiple regression analysis on composite variables for pre/post gain to learn the independent contribution of specific demographic categories.[xv] This analysis shows the independent contribution of each demographic variable toward predicting gain from pre to post on each composite variable. Numbers are standardized regression coefficients. All dependent variables were composites.

Table 17: Multiple regression analysis for gender, science major, ethnicity, GPA and class standing.

	SCIENCE LITERACY	GENERAL SCIENCE	SCIENCE LITERACY INTEREST	"ADVANCED" SCIENCE INTEREST
GENDER (MALE = 1)	-.059**	-.064**	-.064**	.001
SCIENCE MAJOR (SCIENCE MAJ = 1)	-.070**	-.032	-.032	-.169**
WHITE	-.023	-.038*	-.038*	.010
AFRICAN-AMERICAN/NON	-.009	.011	.011	.017
ASIAN	-.043*	-.028	-.028	.015
HISPANIC	-.054*	-.028	-.007	.01
GRADE POINT AVERAGE	-.007	-.024	-.024	-.036*
FRESHMAN	.048	.056	.056	-.010
SOPHOMORE	.039	.018	.018	.009
JUNIOR	.040	.009	.009	.024
SENIOR	.04*	-.02	-.04*	.038

6. Are specific approaches in content, instruction and implementation associated with more less gain from pre to post on SENCER variables?

Linked Student-Instructor Analysis

As of June, 2005, 55 instructors[xvi] in 345 courses provided information for analysis from the faculty survey, records and interviews. This information was linked to the SENCER-SALG responses of 10,387 students. The information provides a detailed description of how content, instructional practices and implementation is associated with gain from pre/post on SENCER-SALG items and composite items.

How were content and instructional methods related to gains?

Analysis found that students in survey courses gained more confidence in general science skills such as summarizing main points from journal articles, giving presentations and working collaboratively on science projects than students in case-based courses. Students in case-based courses gained more on items related to interest in science literacy.

Students taking courses without a service-learning component gained more than students in service learning courses on science literacy items such as determining what is valid scientific evidence in the media, as well as general science skills such as finding journal articles in the library, and writing scientific reports.

Including specific instructional methods into instruction was linked to gains in confidence in science literacy. The greatest gains were for students in courses with field activities, presentations, group work and projects. Courses with these four activities were also linked to general course skills, especially on items about writing reports and working collaboratively with others.

The absence of projects and group work predicted gain on advanced science interest items, while including field activities and lab work in courses was linked with gains on advanced science items. Likewise, the absence of course communication systems (“clickers”) was linked with gains for items in science literacy and general course skills, as were the absence of the use of electronic discussion forums for work outside of class. However, the use of computers in class and the use of computer simulations were positively associated with all composite variables.

See tables 18 – 25 for complete results.

How did implementation affect gain?

Courses were coded as experiencing implementation problems when over 25% of students in each course answering open-ended questions on the SENCER-SALG complained about some aspect of logistical implementation. Thirteen courses accounting for 5,242 students were categorized as experiencing implementation problems. Common complaints included poor integration and coordination of course activities, lack of fit between instruction and assessment, poorly organized group work, dissatisfaction with use of technology (e.g., too much Power Point), and grading perceived as arbitrary. Interestingly, the frequency of complaints showed that courses tended to either experience many, or almost no negative comments.

Courses with implementation problems showed lower gains than those without problems especially with general science items such as understanding mathematical formulas and finding scientific journal articles in the library. Interest in advanced science activities showed the most difference with interest in taking additional courses, and interest in joining a science club significantly greater for students in courses with implementation problems. The results of this analysis are presented in tables 25-29.

Much larger differences were found for "help me learn" items.[xvii] Almost all items except those related to external course activities showed differences favoring students in courses without implementation problems. The largest differences were for ratings of lab, computer and group work as well as presentations and projects. Student ratings were also different (favoring no implementation problems) for the item asking students how course activities related to each other. (See table 29 for these results.)

How did class size relate to gain and implementation?

Class size correlated at almost zero with gain on all SENCER-SALG items related to confidence and interest.

Were students in courses with a service-learning component more likely to say they would engage in these activities than students who did not have service learning?

Students in courses with a service-learning component were more likely to be already active in civic activities than their peers in courses without service learning. However, for many of the activities the difference between the two groups widened when asked their likelihood of engaging in the activity at the end of the course.[xviii] This suggests that courses with service learning/community projects may encourage students to become more active in these areas.

What does the analysis say overall about content, instructional methods and implementation?

Overall, students in survey and non-service-learning courses gained more confidence in general course skills than their peers in case-based courses; students in case-based courses gained more in the science literacy area. Instructional methods such as projects, group work, presentations and field work are associated with greater gains. The use of computers in class for simulations was also linked with gains for several composite variables, but the use of clickers and discussion boards were not. Pre-post gains were less in courses with implementation problems.

<u>How to read the graphs:</u>

Student analysis used dichotomous variables (0/1) to compare pre/post gain for specific instructional methods (i.e., group work v. no group work). The tables presented below (tables 18 -25) compared raw gain on five-point scale items from pre/post for content areas and instructional methods. The number reported is the difference in gain (on a five point scale) by those using the method compared with those not using the method. Numbers in bold show groups significantly different from each other.[xix] Negative numbers indicate that students in the group without the method (i.e., no group work) gained more.

Table 18: Differences in pre/post gain for content and instruction (Confidence in Science Literacy)

	Case/ survey	Civic/ non	Projects	Class discussion	Field activity	Group Work	Lab Work	Presentations
I am confident I can discuss scientific concepts with friends or family (gain)	0.06	0.03	0.06	0.01	**0.20**	0.04	0.05	**0.10**
I am confident I can think critically about scientific readings in the media (gain)	-0.04	-0.08	**0.16**	0.02	**0.14**	**0.13**	0.01	**0.20**
I am confident I can determine what is and isn't valid scientific evidence in the media (gain)	-0.08	**-0.10**	**0.14**	0.01	**0.14**	**0.14**	0.02	**0.21**
I am confident I can make an argument using scientific evidence (gain)	0.01	-0.02	0.06	-0.06	**0.21**	0.06	**0.12**	**0.11**
I am confident I can determine the difference between science and pseudo-science (gain)	-0.13	**-0.21**	**0.15**	-0.04	**0.12**	**0.20**	**0.10**	**0.22**
Science Literacy Composite Gain	-.18	-.40	**0.56**	-0.09	**0.78**	**0.51**	0.31	**0.79**
Average Gain	-0.04	-0.08	0.11	-0.01	0.16	0.11	0.06	0.17

Table 19: Differences in pre/post gain for content and instruction (Confidence in General Science Skills)

	Case/ survey	**Civic/ non**	**Projects**	**Class discussion**	**Field activity**	**Group Work**	**Lab Work**	**Presentations**
I am confident I can interpret tables and graphs (gain)	-0.01	-0.03	**0.11**	-0.06	**0.24**	**0.18**	**0.12**	**0.15**
I am confident I can understand math/stat formulas found in texts (gain)	0.06	0.02	0.17	0.00	**0.47**	**0.32**	**0.18**	**0.20**
I am confident I can find scientific journal articles using library/internet databases (gain)	**-0.37**	**-0.48**	**0.47**	0.30	-0.08	**0.39**	**-0.26**	**0.54**
I am confident I can extract main points from a scientific article and make summary (gain)	**-0.14**	**-0.23**	**0.25**	0.06	0.10	**0.24**	-0.02	**0.31**
I am confident I can give a presentation about a science topic to a class (gain)	**-0.14**	**-0.21**	**0.34**	**0.23**	**0.17**	**0.26**	-0.03	**0.44**
I am confident I can obtain scientific data in a lab or field setting (gain)	-0.10	**-0.24**	0.03	-0.09	**0.29**	**0.24**	**0.28**	**0.11**
I am confident I understand how scientific research is carried out (gain)	-0.05	**-0.14**	0.07	-0.08	**0.24**	**0.12**	**0.24**	**0.12**

Table 19: Differences in pre/post gain for content and instruction (Confidence in General Science Skills) (cont.)

	Case/ survey	Civic/ non	Projects	Class discussion	Field activity	Group Work	Lab Work	Presentations
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence (gain)	-0.09	**-0.18**	**0.12**	-0.04	**0.17**	**0.16**	**0.17**	**0.18**
I am confident I can organize a systematic search for relevant data to answer question (gain)	-0.04	**-0.15**	**0.22**	0.09	**0.19**	**0.19**	0.07	**0.25**
I am confident I can write reports using scientific data as evidence (gain)	**-0.18**	**-0.33**	**0.28**	0.11	0.08	**0.28**	0.01	**0.34**
I am confident I can work with others collaboratively on scientific project (gain)	**-0.22**	**-0.36**	**0.23**	0.05	0.07	**0.28**	**0.14**	**0.30**
I am confident I can apply scientific information to social concerns (gain)	**0.19**	**0.14**	-0.04	0.06	0.07	**-0.26**	-0.01	0.00
Confidence in General Science Skills Composite Variable	**-.96**	-1.7	**1.98**	0.75	**1.95**	**2.64**	**0.77**	**2.59**
Average Gain	-0.09	-0.18	0.19	0.05	0.17	0.20	0.07	0.25

Table 20: Differences in pre/post gain for content and instruction (Interest in Science Literacy)

	Case/ survey	**Civic/ non**	**Projects**	**Class discussion**	**Field activity**	**Group Work**	**Lab Work**	**Presentation s**
I am interested in discussing science with family or friends (gain)	0.09	**0.10**	-0.08	-0.04	0.04	**-0.16**	0.04	-0.07
I am interested in reading about science and relation to civic issues (gain)	0.06	0.08	0.01	-0.03	0.04	-0.06	-0.02	0.03
I am interested in reading articles about science (gain)	0.06	0.07	-0.01	0.00	0.06	-0.08	-0.01	0.02
Science Literacy Interest Composite Variable	**.21**	.21	-0.09	-0.07	0.14	**-0.30**	0.03	-0.03
	0.07	0.08	-0.03	-0.02	0.05	-0.10	0.00	-0.01

Table 21: Differences in pre/post gain for content and instruction (Advanced science interest)

	Case/ survey	Civic/ non	Projects	Class discussion	Field activity	Group Work	Lab Work	Presentation s
I am interested in taking additional science courses after this one (gain)	0.02	-0.01	**-0.12**	-0.15	**0.13**	-0.04	**0.14**	**-0.11**
I am interested in majoring in a science related field (gain)	-0.02	-0.05	-0.06	0.00	0.03	-0.05	0.03	-0.06
I am interested in exploring career opportunities in science (gain)	-0.01	-0.01	-0.06	-0.01	0.03	-0.07	0.03	-0.04
I am interested in joining a science club or organization (gain)	0.04	0.00	-0.05	-0.05	0.07	-0.04	0.06	-0.04
I am interested in attending grad school in a science related field (gain)	0.04	0.01	-0.05	0.02	0.05	-0.08	0.03	-0.04
Advanced Science Interest Composite Variable	.11	-.03	**-0.39**	-0.13	**0.38**	**-0.30**	0.25	-0.26
Average Gain	0.01	-0.01	-0.07	-0.04	0.06	-0.06	0.06	-0.06

Table 22: Differences in pre/post gain for content and instruction (Confidence in Science Literacy)

	Clickers	Simulations	Video/media	Electronic Discussion	Individual work	Computer in class	Other web based
I am confident I can discuss scientific concepts with friends or family (gain)	**-0.19**	0.05	0.04	0.03	**0.10**	**0.11**	0.09
I am confident I can think critically about scientific readings in the media (gain)	**-0.30**	**0.17**	**0.11**	-0.09	**0.17**	0.08	0.02
I am confident I can determine what is and isn't valid scientific evidence in the media (gain)	**-0.31**	**0.20**	0.06	-0.08	**0.15**	0.07	0.03
I am confident I can make an argument using scientific evidence (gain)	**-0.22**	0.06	0.03	0.02	0.07	**0.14**	0.11
I am confident I can determine the difference between science and pseudo-science (gain)	**-0.33**	**0.20**	0.08	**-0.13**	**0.16**	**0.12**	0.00
Science Literacy Confidence Composite variable.	**-1.32**	**0.65**	0.31	-0.23	**0.65**	**0.52**	0.24
Average Gain	-0.27	0.14	0.06	-0.05	0.13	0.10	0.05

Table 23: Differences in pre/post gain for content and instruction (Confidence in General Science Skills)

	Clickers	Simulations	Video/media	Electronic Discussion	Individual work	Computer in class	Other web based
I am confident I can interpret tables and graphs (gain)	**-0.26**	0.03	-0.05	**-0.10**	**0.10**	**0.13**	0.01
I am confident I can understand math/stat formulas found in texts (gain)	**-0.37**	-0.07	**-0.25**	**-0.25**	**0.16**	**0.22**	0.05
I am confident I can find scientific journal articles using library/internet databases (gain)	**-0.60**	**0.71**	**0.40**	**-0.38**	**0.50**	**-0.21**	**-0.20**
I am confident I can extract main points from a scientific article and make summary (gain)	**-0.42**	**0.33**	**0.17**	**-0.19**	**0.26**	0.05	-0.05
I am confident I can give a presentation about a science topic to a class (gain)	**-0.49**	**0.37**	**0.20**	**-0.21**	**0.35**	0.03	-0.05
I am confident I can obtain scientific data in a lab or field setting (gain)	**-0.29**	0.05	-0.04	**-0.14**	0.03	**0.28**	**0.14**
I am confident I understand how scientific research is carried out (gain)	**-0.29**	0.08	0.04	-0.03	0.05	**0.27**	0.11
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence (gain)	**-0.31**	**0.13**	0.04	-0.10	0.11	**0.19**	0.03

Table 23: Differences in pre/post gain for content and instruction (Confidence in General Science Skills) (cont.)

	Clickers	Simulations	Video/media	Electronic Discussion	Individual work	Computer in class	Other web based
I am confident I can organize a systematic search for relevant data to answer question (gain)	**-0.37**	**0.22**	**0.12**	-0.12	**0.22**	**0.12**	-0.02
I am confident I can write reports using scientific data as evidence (gain)	**-0.50**	**0.36**	**0.20**	**-0.25**	**0.27**	0.07	-0.02
I am confident I can work with others collaboratively on scientific project (gain)	**-0.50**	**0.30**	**0.18**	**-0.29**	**0.22**	0.18	0.03
I am confident I can apply scientific information to social concerns (gain)	-0.03	0.02	**0.12**	**0.31**	-0.03	0.08	0.06
General Science Skills Confidence Composite Variable	**-3.86**	**2.03**	**0.74**	-1.89	**1.91**	**1.14**	-0.34
Average Gain	-0.37	0.21	0.09	-0.15	0.19	0.12	0.01

Table 24: Differences in pre/post gain for content and instruction (Interest in Science Literacy) (cont.)

	Clickers	**Simulations**	**Video/media**	**Electronic Discussion**	**Individual work**	**Computer in class**	**Other web based**
I am interested in discussing science with family or friends (gain)	0.05	-0.05	**0.11**	**0.23**	-0.08	0.08	0.05
I am interested in reading about science and relation to civic issues (gain)	-0.05	0.01	0.07	0.11	0.01	0.06	-0.03
I am interested in reading articles about science (gain)	-0.04	0.02	0.10	**0.13**	0.00	0.07	-0.03
Science Literacy Interest Composite Variable	-0.04	-0.02	**0.27**	**0.48**	-0.07	0.21	0.02
Average Gain	-0.01	-0.01	0.09	0.16	-0.02	0.07	0.00

Table 25: Differences in pre/post gain for content and instruction (Interest in "Advanced" science)

	Clickers	Simulations	Video/media	Electronic Discussion	Individual work	Computer in class	Other web based
I am interested in taking additional science courses after this one (gain)	-0.05	-0.07	-0.05	**0.13**	**-0.11**	**0.17**	**0.14**
I am interested in majoring in a science related field (gain)	0.03	-0.02	0.03	0.08	-0.04	0.03	0.01
I am interested in exploring career opportunities in science (gain)	0.02	-0.01	0.02	**0.11**	-0.05	0.04	0.03
I am interested in joining a science club or organization (gain)	0.00	-0.03	0.00	**0.11**	-0.04	0.03	0.03
I am interested in attending grad school in a science related field (gain)	0.06	-0.03	0.03	**0.14**	-0.04	-0.01	0.04
Advanced Science Interest Composite Variable	0.10	-0.16	0.03	**0.63**	-0.31	0.27	0.12
Average Gain	0.01	-0.03	0.01	0.11	-0.06	0.05	0.05

Table 26: Comparison of gain in courses with implementation and no implementation problems (Confidence in Science Literacy)

Item	Difference: No implementation problems – courses with implementation problems
I am confident I can discuss scientific concepts with friends or family (gain)	0.07
I am confident I can think critically about scientific readings in the media (gain)	0.01
I am confident I can determine what is and isn't valid scientific evidence in the media (gain)	0.00
I am confident I can make an argument using scientific evidence (gain)	0.08
I am confident I can determine the difference between science and pseudo-science (gain)	0.01
Science Literacy Composite Variable	0.17
Average Gain	.03

Table 27: Comparison of gain in courses with implementation/ no implementation problems (Confidence in General Science Skills)

Item	**Difference: No implementation problems – courses with implementation problems**
I am confident I can interpret tables and graphs (gain)	**0.13**
I am confident I can understand math/stat formulas found in texts (gain)	**0.28**
I am confident I can find scientific journal articles using library/internet databases (gain)	**0.37**
I am confident I can extract main points from a scientific article and make summary (gain)	-0.08
I am confident I can give a presentation about a science topic to a class (gain)	-0.02
I am confident I can obtain scientific data in a lab or field setting (gain)	**0.21**
I am confident I understand how scientific research is carried out (gain)	**0.12**
I am confident I can pose questions that can be addressed by collecting and evaluating scientific evidence (gain)	0.07
I am confident I can organize a systematic search for relevant data to answer question (gain)	0.00
I am confident I can write reports using scientific data as evidence (gain)	**-0.10**
I am confident I can work with others collaboratively on scientific project (gain)	-0.03
I am confident I can apply scientific information to social concerns (gain)	-0.03
General Science Skills Composite Variable	**0.92**
Average Gain	**.08**

Table 28: Comparison of gain in courses with implementation and no implementation problems (Interest in Science Literacy)

Item	Difference: No implementation problems – courses with implementation problems
I am interested in discussing science with family or friends (gain)	0.02
I am interested in reading about science and relation to civic issues (gain)	0.02
I am interested in reading articles about science (gain)	0.02
Interest in Science Literacy Composite Variable (gain)	0.06
	0.02

Table 29: Comparison of gain in courses with implementation and no implementation problems (Interest in Advanced Science)

Item	**Difference: No implementation problems – courses with implementation problems**
I am interested in taking additional science courses after this one (gain)	**0.18**
I am interested in majoring in a science related field (gain)	0.06
I am interested in exploring career opportunities in science (gain)	**0.08**
I am interested in joining a science club or organization (gain)	**0.09**
I am interested in attending grad school in a science related field (gain)	0.06
I am interested in teaching science (gain)	0.07
Interest in Advanced Science Composite Variable (gain)	**0.51**
Average	**.09**

Table 30: Comparison of gain in courses with implementation and no implementation problems ("Helped me Learn" Items)

How much did each of the following help your learning?"

Item	**Difference: No implementation problems – courses with implementation problems**
Activities: Lecture	**0.38**
Activities: Discussion	**0.54**
Activities: Group work	**0.59**
Activities: Individual work	**0.29**
Activities: Lab	**0.70**
Activities: Computer	**0.61**
Activities Media	**0.22**
Graded: Written	**0.31**
Graded: Oral presentations	**0.47**
Graded: Projects	**0.47**
Graded: In class review	**0.25**
Graded: Receiving feedback	**0.54**
Resources: Text	**-0.10**
Resources: other resources	**0.19**
External: Studying individually	-0.06
External: Studying with partner	0.06
External: Studying with group	0.06
External: Help from TA	-0.10
External: Help from instructor outside class	**0.62**
How course activities relate	**0.65**

7. What is the validity evidence for the SENCER-SALG? How can the SENCER-SALG be best utilized by instructors?

Revision and Validation of the SENCER SALG

The SENCER-SALG was modified from the original *Student Assessment of Learning Gains* (SALG) instrument designed and developed by Elaine Seymour and Susan Lottridge. The SENCER-SALG retains "core" items of the SALG focused on student ratings of "what helped" learning, while adding items asking student to rate their confidence in science skills, interest in science and engagement in civic activities. The survey is given pre/post thus letting instructors examine gain on specific items and groups of items.

Evaluators assessed the validity of the SENCER-SALG by collecting evidence from a range of sources. Basic validity areas included descriptive analysis of item functioning, matches with instruments hypothesized to correlate with the survey, examination of how items relate to each other, and feedback from interview and surveys on how the survey is used for its intended purpose. The broad purpose of collecting validity evidence for the SENCER-SALG was to learn if the survey functions as designed, and if it provides meaningful information to its users.

<u>Item Functioning</u> Most items on the survey function adequately. This means that, on the average, students provided responses across the range of possible choices, and averages did not group themselves too near the top, or bottom of item scales. Some items on the survey were found to be redundant and will be eliminated from the final version of the instrument.

<u>Composite Variables</u> One way in which survey variables are used analytically is through composites, usually formed by simple, or weighted summations of responses across items. Composites of items on the SENCER-SALG were found to be stable in that averages stayed within a limited range across semesters and across institutions, and increased uniformly from pre to post versions. Subscales were also found to have the psychometric quality of internal reliability, meaning the survey would tend to return the same result if administered multiple times to the same students. Composites of items for the SENCER-SALG include *Confidence in Science Literacy Skills*, *Confidence in General Science Course Skills, Interest in Science Literacy, Interest in "Advanced" Science Activities,* and *Student Civic Engagement.*

<u>Factor Analysis</u> Composite variables were (in part) derived from the statistical technique of factor analysis. Factor analysis identifies how survey items relate to each other in terms of underlying factors. Exploratory factor analysis of results found four factors corresponding to the subscales shown above, with an additional factor for civic engagement not included as a composite. Factor analysis also provides a way of learning how factors relate to each other. Broad factors for *Confidence in Science Skills* and

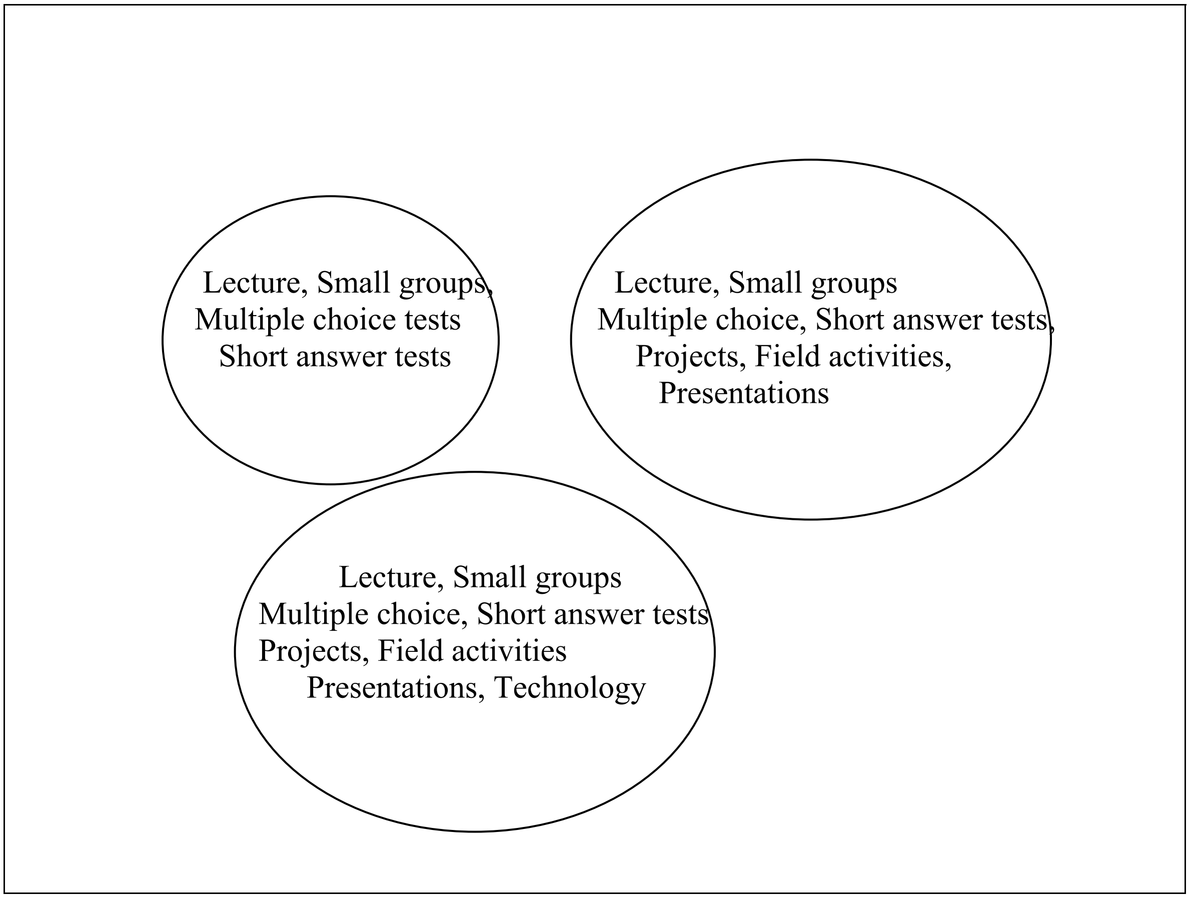
Interest in Science were moderately correlated (r = .4); *Civic Engagement* was largely independent of confidence and interest. Factor structure did not meet the higher standard of significance used for *Confirmatory Factor Analysis,* a method of testing pre-determined factor structures.

Criterion Validity A common method of validating surveys and tests is to compare how people respond on one measure with their responses on another related measure, sometimes called a "criterion" measure. For the SENCER-SALG, student survey responses were matched with student grades. It was expected that student confidence in science skills and their interest in science would be moderately associated with their performance in class on measures of content knowledge. Criterion matches of composite subscales with grades were lower than expected, with moderately low (r= .3) correlations between confidence and interest (on one hand) and grades, and no correlation between civic engagement and grades. The criterion studies were conducted in large chemistry and biology courses at two institutions.

Consequential Validity An important validity question for the SENCER-SALG is its utility for making course design revisions. Of those instructors reporting on use of the SENCER-SALG, (79%) said they used the instrument to make substantive changes to their courses such as greater integration of civic content. Other course changes such as adding or dropping modular labs, dropping the use of textbooks, or adding online exercises were also described by instructors. All but two instructors said the SENCER-SALG provided feedback substantially different from their traditional course evaluations.

A journal article *The Validity of the SENCER-SALG* (Weston, Seymour, Lottridge, Thiry, 2006) was written describing these findings in more detail.

Figure 7: Three typical groups of instructional methods used by SENCER instructors.



APPENDIX

SENCER Student Assessment of Learning Gains (SALG)

HOW MUCH did each of the following HELP YOUR LEARNING?

Course focus on:

Addressing real-world issues [such as…]	NA	No help	A little help	Moderate help	Much help	Very much help
Interplay between science and civic issues	NA	No help	A little help	Moderate help	Much help	Very much help
Gathering scientific data in labs or in the field	NA	No help	A little help	Moderate help	Much help	Very much help
Analyzing scientific data	NA	No help	A little help	Moderate help	Much help	Very much help
Using scientific methods	NA	No help	A little help	Moderate help	Much help	Very much help
Learning scientific facts	NA	No help	A little help	Moderate help	Much help	Very much help
Learning how real science is done	NA	No help	A little help	Moderate help	Much help	Very much help
Summarizing scientific results	NA	No help	A little help	Moderate help	Much help	Very much help
(Instructor add)	NA					

HOW MUCH did each of the following HELP YOUR LEARNING?

The class activities:

Presentations/lectures from course instructor(s)	NA	No help	A little help	Moderate help	Much help	Very much help
Discussions in class	NA	No help	A little help	Moderate help	Much help	Very much help
Group work in class	NA	No help	A little help	Moderate help	Much help	Very much help
Individual work in class	NA	No help	A little help	Moderate help	Much help	Very much help
Lab activities	NA	No help	A little help	Moderate help	Much help	Very much help
Computer-based work	NA	No help	A little help	Moderate help	Much help	Very much help
Media such as videos, film or slides	NA	No help	A little help	Moderate help	Much help	Very much help
(Instructor add)	NA	No help	A little help	Moderate help	Much help	Very much help

HOW MUCH did each of the following HELP YOUR LEARNING?

Graded activities and assignments:

Completing written assignments (individual or group)	NA	No help	A little help	Moderate help	Much help	Very much help
Preparing for oral presentations (individual or group)	NA	No help	A little help	Moderate help	Much help	Very much help
Participating in group/team projects	NA	No help	A little help	Moderate help	Much help	Very much help
Receiving in-class review before tests	NA	No help	A little help	Moderate help	Much help	Very much

						help
Receiving feedback on our work	NA	No help	A little help	Moderate help	Much help	Very much help
(Instructor add)						

HOW MUCH did each of the following HELP YOUR LEARNING?
Resources:

Studying course text	NA	No help	A little help	Moderate help	Much help	Very much help
Studying other readings	NA	No help	A little help	Moderate help	Much help	Very much help
(Instructor add)						

External class activities

Studying individually	NA	No help	A little help	Moderate help	Much help	Very much help
Studying with a partner	NA	No help	A little help	Moderate help	Much help	Very much help
Studying with a group	NA	No help	A little help	Moderate help	Much help	Very much help
Receiving help from a TA	NA	No help	A little help	Moderate help	Much help	Very much help
Receiving help from the instructor outside of class	NA	No help	A little help	Moderate help	Much help	Very much help
(Instructor add)	NA	No help	A little help	Moderate help	Much help	Very much help

The information we were given about:

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

(Instructor add)						

Open-ended: **What course activity helped you learn the most? Describe why it helped you learn.**

After finishing this class, I am CONFIDENT I can…

Discuss scientific concepts with my friends or family	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Think critically about scientific findings I read about in the media	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Determine what is -- and is not -- valid scientific evidence in the media	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Make an argument using scientific evidence to friends of family	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Determine the difference between science and "pseudo-science" in the media	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

After finishing this class, I am CONFIDENT I can…

Interpret tables and graphs	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Understand mathematical and statistical formulas commonly found in scientific texts	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Find scientific journal articles using library/internet databases	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Extract main points from a scientific article and develop a coherent summary	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Give a presentation about a science topic to your class	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Obtain scientific data in a laboratory or field setting.	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Understand how scientific research is carried out	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Pose questions that can be addressed by collecting and evaluating scientific evidence	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Organize a systematic search for relevant data to answer a question	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Write reports using scientific data	Not	A little	Somewhat	Highly	Extremely

as evidence	confident	confident	confident	confident	confident
Work with others collaboratively on a scientific project	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
Apply scientific information to social concerns	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

After finishing this class, I am CONFIDENT I can…

(Instructor add)	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
(Instructor add)	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
(Instructor add)	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident
(Instructor add)	Not confident	A little confident	Somewhat confident	Highly confident	Extremely confident

Open-ended Question: Are there any other skills you believe you gained from the course not listed above?

After finishing this class, I am INTERESTED in…

Discussing science with friends or family	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Reading about science and its relation to civic issues	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Reading articles about science in magazines, journals or on the internet	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Taking additional science courses after this one	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Majoring in a science-related field	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Exploring career opportunities in science.	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Joining a science club or organization	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Attending graduate school in a science-related field	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Teaching science	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Participating in an internship with a scientific organization or laboratory	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested

Learning more about other scientific disciplines	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Volunteering for science-related community service	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
Participating in non-formal science education at a museum or a school	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested

(Instructor add)	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
(Instructor add)	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
(Instructor add)	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested
(Instructor add)	Not at all interested	A little interested	Somewhat interested	Highly interested	Extremely interested

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

After finishing this class, I am more likely to…

Discuss a science-related issue informally	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Discuss a civic or political issue informally	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Read a science-related magazine not required by class	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Write a letter or emailed a public official about a political issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Write a letter or email a public official about a science-related issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Talk with a public official about a civic or science-related issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Debate or offer public comment on a scientific issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Debate or offer public comment on a civic or political issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Attend a meeting, rally or protest about a civic or political issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Write a letter to the editor about a civic or political issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Write a letter to the editor about a science-related issue	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Join a science-related civic organization	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Participate in science-related civic education	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Do an internship at a civic organization	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Work or volunteer for a political campaign	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Participate in one-time civic events such as walk-a-thons	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Vote in elections	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

(Instructor add)					
(Instructor add)					
(Instructor add)					
(Instructor add)					

End Notes

[i]National Research Council (2003). *Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics,* presented by: The committee on recognizing, evaluating, rewarding, and developing excellence in teaching of undergraduate science, mathematics, engineering, and technology, (Washington, DC, National Academy Press).

[ii] Project Kaleidoscope, The Council on Undergraduate Research, and Chemlinks run workshops, design curricula and encourage reform practices. Numerous programs and centers at individual universities also enable better teaching.

[iii] Because this data is from a school known to project PI's, we cannot directly compare in a report results with and without these students because of IRB requirements.

[iv] The number of SENCER courses is most likely "numbered in the hundreds" according to SENCER.

[v] Records included SENCER models, syllabi from instructors and course materials given to us by instructors. We used SENCER models to illustrate categories because of IRB requirements.

[vi] Scaling involves plotting the total number of methods used against the probability of using any particular method. The continuous scale was divided in three parts. If the probability is over .50 for the method it was included in the group.

[vii] This comparison used a chi-square test with chi-square = 4851, df = 1. This result shows a strong relationship between the two variables. In terms of a correlation coefficient the two variables are related at r = .675.**

[viii] These comparisons were made with t-tests for independent groups. An alpha level of .01 was used as a standard for significance. Because of the large numbers of students, use of t-tests for these comparisons were robust to non-normality in distributions due to the use of proportional data.
Treating ordinal survey data as numerical (e.g., using means) is commonly practiced in large surveys such as the NAEP teacher survey. It is necessary to do so especially when ranking items in a set.

[ix] Foertsh, J. M., Millar, S. B., Squire, L. , & Gunter, R. (1997). Persuading professors: A study in the dissemination of educational reform in research institutions. Report to the NSF Education and Human Resources Directorate, Division of Research, Evaluation, and Communication. Washington DC. Madison: University of Wisconsin- Madison, LEAD Center.

[x] Seymour, E., Larsen, S. (2005) Student Resistance and Student Learning in Undergraduate Science Classes Using Active Learning Pedagogies. White Paper: Evaluation and Ethnography Research, Boulder, CO.

[xi] Responses from a group of non-SENCER courses included in early analyses were not included in this analysis.

[xii] These ratings were only compiled in courses identified as using these methods.

[xiv] Analysis was conducted to learn if differences could be explained by "regression toward the mean" given the reliability of the composites. As a rule, lower scoring groups on a pre-measure will gain more than higher scoring groups.

[xv] Regression is used to tease out the independent contribution because demographic groups are frequently confounded with each other. For instance, it is possible that proportionally more men tend to be science majors than women, so any comparison based on science major may have be covering a gender difference.

Different ethnic/racial groups and class standing groups were coded as dichotomous variables. Regression was done in multiple tries with one group (e.g. African-Americans) taken out of the analysis as an anchor group. Estimates for individual groups were stable across tries.

[xvi] Information varied by survey items. The minimum number of instructors with information on any variable was 43. Instructors who gave the SALG but did not answer the survey only accounted for approximately 400 students.

[xvii] Again, only those courses who included the method were included in the analysis.

[xviii] This comparison was conducted with an Analysis of Covariance. This procedure holds the pre score constant and compares the post score with this adjustment.

[xix] These comparisons used t-tests with a .01 standard for significance.