Board of Science Education
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in STEM Undergraduate Education

Chemistry in Context: Goals, Evidence, and Gaps

(A White Paper)

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Overview

This White Paper describes a project of the American Chemical Society (ACS) that clearly has been successful: *Chemistry in Context*. Faculty adoption of the text has steadily increased over the past six editions. Evidence shows that students who are non-science majors learn chemistry and are interested and engaged learners.

In the opening sections, this paper describes the project, the impetus for its origin in 1989, the key attributes that distinguish this project, and the challenges that these attributes present to instructors. In broadest terms, the goals for the project are presented. Some of these goals relate to the content that students have learned and the attitudes that they have acquired. Here the “grain size” is at the level of the course and its instructor. Other goals relate to outcomes at the national level such as the adoption of the text and its influence on other national reform efforts. Here the “grain size” is considerably larger. Given the range of project goals, *many different forms of evidence are appropriate* to support these goals.

In the middle sections, this paper examines the quality of the evidence and how this evidence is likely to relate to the uptake of the project. In part, the uptake rests on evidence that directly relates to the student learning goals associated with the project. While compelling to individual instructors, this evidence is largely unpublished and without a consistent format. The uptake of the project also rests on broader evidence such the number of textbooks sold, the continued attendance at faculty workshops, and the translation of the book into other languages. These forms of evidence, while significant, are not necessarily widely known to the instructors who use the text.

This paper concludes by suggesting that the evidence collected to date, while influential, in and of itself *may not be sufficient to account for the success of the project*. Two other factors may be equally influential and possibly even more so. The first is professional societies and their influence on both individuals and institutions. The second is the urgent issues present in our world (based in part on science) and their influence on colleges and universities.

The Board on Science Education provided these questions to guide the discussion:

1) What are and what should be some of the most important learning goals for science students in lower division courses? We are interested in goals over a range of grain sizes from activities within an individual course to college-wide efforts, although you do not need to focus on all levels in your "thought paper."

2) In the context of the learning goals you identified, what types of evidence would be needed in order to conclude that a specific goal had been achieved?

3) With so many forms of evidence available to us in science education, are there some types of evidence that carry more weight in your experience? If so, what makes that evidence particularly compelling?

4) As you consider learning goals and evidence, where are the biggest gaps in evidence in science undergraduate education?

5) How important has the quality of evidence been in influencing or guiding the widespread uptake of a promising practice? Can you identify specific examples where the presence or absence of evidence of effectiveness has had a major impact on dissemination or usage by faculty?

I. Background

"How is what you are teaching connected to the real world?" This question was no less pressing in the 1980s than it is today. To answer it, in 1989 the American Chemical Society launched a project that led to the publication of the first edition of *Chemistry in Context: Applying Chemistry to Society*. The first of its kind, this college textbook for non-science majors connected chemical principles to real-world issues and their social, economic, political and global contexts.

The book met a demonstrated need. The original project leaders recognized that it was simply unacceptable that so many non-science students perceived their chemistry courses to be an unpleasant learning experience. To quote the original author team: "The fact remains that this large population is often ill served, if served at all, by college and university chemistry departments."[1]

Although a new approach was needed, textbook publishers and most authors thought that making changes was too risky. The general chemistry curriculum was sacred ground. Certain topics *had* to be covered (for one reason or another) and these topics *had* to be in the textbook. Existing courses for non-science majors largely offered a watered-down version of the chemical content taught for science majors. The curriculum effectively was in gridlock.

The Education Division of the ACS, under the leadership of Sylvia Ware, thought otherwise. The Division already had scored a success with the publication of a high school text for college bound non-science majors, *Chemistry in the Community* ("*ChemCom*").[2] Ware also recognized that courses for non-science majors generally were considered low-status and mostly off faculty radar screens. Since non-science majors were unlikely to take any further science classes, the topics that they studied were of much less concern. Thus for non-science majors, it seemed possible to take a new approach.

In 1989, Ware appointed a blue-ribbon advisory board chaired by Ronald A. Archer. A. Truman Schwartz, who recently had served as a member of the AAAS *Project on Liberal Education and the Sciences*,[3] was named as the Editor-in-Chief. In the preface to the first edition, Schwartz recalls the history of *Chemistry in Context*:

> A brief history of the development of the book might help set it in its own context. In many ways, *Chemistry in Context* is the philosophical and intellectual offspring of *ChemCom* and its midwife and godmother is Sylvia Ware, Director of the Education Division of the ACS. *ChemCom*, first published in 1988 by Kendall-Hunt, is a high school text, intended primarily for college-bound students not planning a career in science. It differs from other secondary school books in that the chemistry is embedded in an exploration of broader social issues. …The success and wide acceptance of *ChemCom* prompted a decision to apply a similar pedagogical approach to college chemistry courses for nonscience majors.[4]

Over the years, the leadership of the project has had continuity, with new writers rotating on and off of the team. Conrad Stanitski, a member of the initial writing team, served as the Editor-in-Chief for the third and fourth editions. Sales increased each year for both the third and fourth editions, the first time that this had happened in this market niche. Stanitski appointed new authors, including Lucy Eubanks and Cathy Middlecamp. Eubanks served as Editor-in Chief for the fifth edition (32,800 units sold) and just released sixth edition. Middlecamp is the Editor-in-Chief for the seventh edition, now in preparation.

II. Breaking the Mold: Key Distinguishing Attributes

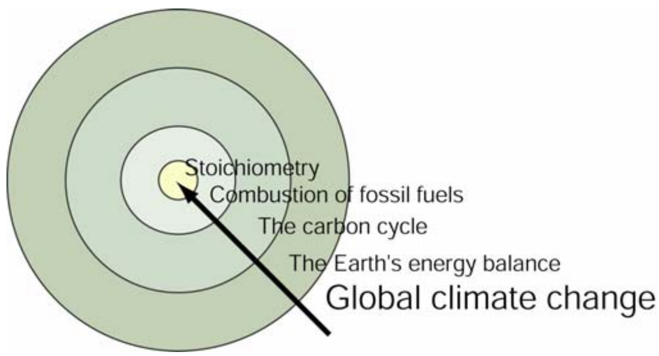
For most instructors, *Chemistry in Context* does not "teach the way we were taught." The project broke the mold – and continues to do so today – in several important ways.

A. The organizing principle is real-world issues.

Each chapter relates to an issue that is significant to society and technologically based; for example, air quality, nuclear energy, global climate change, and drugs. See Appendix A for the complete list.

B. Narratives reach from the real-world into the world of chemistry.

Chemistry in Context begins each chapter with a narrative about a real-world issue, one selected to have a high potential to engage students. The instructional pathway is *from* the real-world *into* the discipline of chemistry. For example, Chapter 3, "The Chemistry of Global Warming" teaches through the issue of global climate change to the underlying chemical principles of combustion and stoichiometry (see below). The instructional pathways for two other chapters are shown in Appendix B.



C. The content is presented on a "need-to-know" basis.

The selection and placement of chemical principles in *Chemistry in Context* is driven by what students *need to know* in order to understand the science related to each real-world issue. For example, students need to know basic stoichiometry to calculate the amount of CO_2 released when a gallon of gasoline is burned. Therefore the mole concept is introduced in the global warming chapter rather than in a stand-alone section in a stoichiometry chapter.

The approach is focused and forces the author team to be selective. Omissions are intentional. The authors do not add chemical concepts to the chapters – major ones or minor – for the sake of "coverage." For example, since none of the real-world issues selected require knowledge of hybrid orbitals, this concept is omitted. However, students *do* need knowledge of the Chapman cycle[1], a topic not commonly presented in a first-year chemistry course, to understand the thinning of the stratospheric ozone layer. The need-to-know approach does not "water down" chemistry for non-science majors.

D. The content is inherently interdisciplinary.

The real world is not bounded the same artificial ways as are our scientific disciplines. To help students fully understand the issues, content both from other scientific fields and from the humanities and social sciences may be needed. For example, the biological effects of ionizing radiation are needed to understand the hazards of radioactive waste; and political and economic analyses are needed to understand air quality standards and how they change over time.

[1] A set of reactions of O, O_2 and O_3 that occur in the stratosphere, named after the physicist Sydney Chapman.

E. The content is time-sensitive.
Real-world scientific issues are moving targets. Instructors must continually update their knowledge to stay current. For example, new air quality standards are released; the disposal of high level nuclear waste is challenged; the Kyoto Protocol takes effect; and the Intergovernmental Panel on Climate Change releases a new report. Instructors cannot use yesterday's information to teach about the world of today.

III. Challenges in Implementing the Curriculum

Again, *Chemistry in Context* does not "teach the way we were taught." Faculty members, when they first teach with *Chemistry in Context*, are faced with several challenges.[5]

One challenge stems from the real-world issues used as the course organizing principle. Instructors may know little about the chemical concepts associated with topics such as stratospheric ozone depletion, nuclear waste, and biofuels. They may not know which gases do (and do not) come out of the tailpipe of a car. Instructors thus may have a learning curve right along with their students.

The need-to-know basis that drives the selection of chemical content presents a related challenge. If a need-to-know does not exist for a topic, it will not appear in the text. This scenario may require instructors to let go of teaching one or more long-held favorite topics and/or to teach these topics in far less depth.

A third challenge is the time an instructor must invest. This time is spent both in learning new content and in keeping current with scientific developments. The topics of global climate change and nuclear energy are good cases in point.

The final challenge is that instructors may need to rethink the learning goals that they set for their non-science majors and change their instructional practices to better meet these goals. It is to the topic of goals – both for the student and for the project itself – that we now turn.

IV. Goals of the Project

What are and what should be some of the most important learning goals for students in a chemistry course for non-science majors? The original project leaders of *Chemistry in Context* tackled this question head on.

As noted earlier, the original author team recognized that non-science majors were "ill served" by their chemistry courses. More recent evidence backs up this assertion.[6,7,8] College students – our future citizens, voters, and neighbors – were indeed learning something in their general chemistry courses: *They were learning to dislike chemistry*. With a learning experience that was simultaneously distasteful and stressful, these students were unlikely to make gains in chemical literacy.

Accordingly, <u>the project leaders set broadly based learning goals</u>. These goals encompassed attitude and motivation as well as content mastery. The bottom line was that students should learn chemistry. Nonetheless, it was equally important that have a satisfying learning experience. Thus, when students completed their chemistry course, they would have both the motivation and intellectual tools to continue learning chemistry over their lifetime.

In broad terms, the learning goals for *Chemistry in Context* were set forth in the preface to each edition. See, for example, the preface to the current edition that reaffirms the goals carried forward from all previous editions (Appendix C). The project goals also were described in a journal article by the original author team.[9] Although initially the goals were formatted as a list, this list is no longer is in the hands of recent author teams. Even so, it is possible to re-create such a list from the sources just named. The result is presented here, with the goals grouped for the purposes of later discussion.

Note: The term "goal" is used as a broad statement of intention. Each goal is accompanied by a rationale and by sub-goals (green shading), also broadly written. The term "learning objective" (pink shading) refers to a smaller measurable item. These learning objectives, in support of the goals, are taken from the Chapter Summaries of the current sixth edition.[10]

A. Student Attitudes and Motivation toward Learning Chemistry

Goal #1. To give students a positive experience in learning chemistry.

Rationale: "… the fact remains that this large population is often ill served, if served at all, by college and university chemistry departments."[11]

Goal #2. To motivate students to learn chemistry.

Rationale: "For most people, the chief impediment to learning chemistry is not a deficit of intellect, but lack of motivation. This is especially true for those who do not contemplate careers in natural science. Therefore, a major goal of *Chemistry in Context* is to motivate students to learn chemistry."[12]

More specifically, students should:

- Find satisfaction in engaging in real-world issues that require a knowledge of chemistry
- Experience the chemistry course as interesting and worth taking
- Become motivated as life-long learners of chemistry (and of science)

Sample Learning Objectives from 6th edition
Goals #1 and #2 can be inferred from learning objectives such as the ones listed here.

Chapter Three – The Chemistry of Global Warming

- With confidence, examine news articles on energy crises and energy conservation measures and interpret the accuracy of such reports.
- Summarize how human activities contribute to the carbon cycle and through it, to global warming
- Read and hear news stories on global warming with some measure of confidence in your ability to interpret the accuracy and conclusions of such reports.

B. Student Knowledge of Chemistry

Goal #3. To promote broader chemical literacy.

Rationale: "Broader chemical literacy is bound to benefit the American society and, not so incidentally, the American Chemical Society."[13] Hence, it made sense that the ACS was the sponsor for this project. The original author team noted "We thus seek to motivate readers; equip them to locate information; and develop their analytical skills, critical judgment, and the ability to assess risks and benefits." [14]

More specifically, students should:

- Learn the chemical principles that underlie the real-world and pressing issues of our world today
- Be able to locate scientific information needed for a better understanding of these issues
- Develop the critical thinking skills needed to analyze the many dimensions of these issues
- Develop the ability to assess risks and benefits of different scenarios.

Sample Learning Objectives from 6th edition

Chapter One –The Air We Breathe

- List major air pollutants and describe the effects of each on humans.
- Compare and contrast indoor and outdoor air, in terms of which pollutants are likely to be present and their relative amounts.
- Interpret values of the color-coded Air Quality Index and know how to assess local air quality data from the EPA.

Chapter Three – The Chemistry of Global Warming

- Understand the major role that certain atmospheric gases play in the greenhouse effect.
- Explain the methods used to gather past evidence for global warming.
- Compare how the issue of global warming is both similar to and different from the issue of ozone depletion.

Goal #4. To help students better meet the challenges of today's world.
Rationale: "[The approach] should also provide appropriate critical thinking skills for considering other issues that will be of importance in the twenty-first century"[15] and "Above all, we hope to empower our readers to respond with reasoned and informed intelligence to the complexities of our modern technical age."[16]

More specifically, students are to:

- Develop the skills (analytic and critical judgment) needed to use scientific information to make informed decisions
- Be able to respond with reasoned and informed intelligence to issues in local communities, regionally, nationally, and in larger global communities.

Sample Learning Objectives from 6th edition

Chapter One –The Air We Breathe

- Interpret air quality data in terms of concentration units (ppm, ppb) and pollution levels, including unreasonableness of "pollution-free" levels.

Chapter Three – The Chemistry of Global Warming

- Take an informed position with respect to issues surrounding global warming.

Chapter Four – Energy, Chemistry and Society

- Evaluate the risks and benefits associated with petroleum, coal, and natural gas as fossil fuel energy sources.
- Compare and contrast ethanol and biodiesel as fuels.

Beginning with the third edition, *Chemistry in Context* emphasized applications of green chemistry and provided examples in almost every chapter. Green chemistry, however, is a *tool* for achieving sustainability, rather than an end in itself. Bill Carroll (former ACS president) and Douglas Raber highlight the importance of connecting chemistry and sustainability: "By 2015, the chemistry enterprise will be judged under a new paradigm of sustainability."[17,18]

Given the rising awareness of the importance of – if not the urgency for – using resources in a sustainable manner today, the current Editor-in-Chief (Cathy Middlecamp) and the current Director of the ACS Education Division (Mary Kirchhoff) have articulated an additional goal for the seventh edition of *Chemistry in Context*. This goal expands upon **Goal #4** and emphasizes the importance sustainability.

Goal #5. To help students make choices, informed by their knowledge of chemistry, to use natural resources in wise and sustainable ways.[19]

Rationale: Many of the local, regional, and global challenges that we face today are connected to the ways in which we consume resources and produce waste. A knowledge of chemistry can help students to better meet these challenges and to make informed choices as citizens.

More specifically, students are to:

- Evaluate chemical processes using the concepts of green chemistry
- Connect their knowledge of sustainability from other courses to content in their chemistry course
- Understand the urgency of working towards using natural resources in sustainable ways
- Take actions based on this understanding, taking up the challenge of safeguarding the interests of coming generations.

Sample Learning Objectives from 6th edition

Chapter Two – Protecting the Ozone Layer

- Evaluate articles on green chemistry alternatives to stratospheric ozone-depleting compounds and recognize the effect that market forces have on the success of these innovations.

Chapter Four – Energy, Chemistry and Society

- Take an informed stand on what energy conservation measures are likely to produce the greatest energy savings.

Pertaining to **Goals #3**, **#4**, and **#5**, Conrad Stanitski, Editor-in-Chief for the third and fourth editions, with his *Chemistry in Context* colleagues, led over a dozen NSF Short Courses for college instructors using *Chemistry in Context*. At these workshops he was known to quip *"Teaching chemistry majors is a challenging and highly difficult task. You have to prepare them for organic chemistry. In contrast, teaching non-majors is much easier. All you have to prepare them for is life."*

C. Larger Goals of the Project

Three other goals were stated informally for the project as a whole. Although some documentation exists, these goals largely were passed informally from one author team to the next. Admittedly **Goal #7** below is unusual in the sense that textbook publishers and authors might be seen as unlikely candidates to set a goal that loses for them a market share and royalties. However, this goal makes good sense for a *professional society* trying to catalyze widespread change. Members of the author team have not received royalties; rather, they are contracted by the ACS for writing.

Goal #6. To be adopted (and adapted) widely.
Rationale: Adoptions demonstrate that the project is meeting a need at some level: departmental, institutional, or perhaps even societal. Currently, *Chemistry in Context*, the most widely adopted book in its market, draws many of its examples from the United States. Translations of the book, done into other languages and into other regional/cultural contexts, demonstrate that the approach is robust and adaptable.

Goal #7. To catalyze the development of other projects with a similar approach.
Rationale: *Chemistry in Context* broke the mold by using real-world topics as an organizing principle for learning chemistry. An indicator of the success of this approach would be if other books and curricula (perhaps even for science majors) appeared that approached

chemistry in a similar manner. "If the result is greater originality and diversity in chemistry texts and chemistry courses, *Chemistry in Context* will have had an influence well beyond its original intent."[20]

Goal #8. To pave the way for a similar approach for science majors.
Rationale: "If the result is greater originality and diversity in chemistry texts and chemistry courses, *Chemistry in Context* will have had an influence well beyond its original intent."[21]

V. The Evidence, the Weight It Carries, and the Gaps

Although *Chemistry in Context* was class-tested in its design phase, it did not (and still does not) have a formal plan to assess student learning on an ongoing basis. Accordingly, those who adopt the approach must do so on the basis of other evidence. This section pairs the broad goals from the previous section with the forms of evidence that could be used to support them. It also discusses the weight these forms of evidence are likely to carry with different constituencies.

The goals relate either to students or the overall project. None, however, relate directly to the faculty. *This is a significant gap in the evidence.* For example, evidence concerning faculty use of the approach never has been collected. Ethnographic research could well inform why instructors switch to this approach, what exactly they do when they teach their students, and why instructors persist (or not) with the approach.

A. Student Attitudes and Motivation toward Learning Chemistry

This form of evidence pertains to **Goals #1** and **#2** (motivation and engagement in learning). This evidence is primarily local; that is, it resides with instructors at different institutions. It is of variable format. Usually this evidence is collected for the purposes of improving instruction and is not disseminated beyond the department or campus. The available forms of evidence include:

- **Student attitude surveys**
  Surveys about attitudes toward science (in general) and the course (in particular) before and/or at the conclusion of a course.
- **Instructor-centered course survey instruments**
  Course evaluations with questions about how well *the instructor* engaged the students and caught their interest in the course. See sample data in Appendix E.
- **Student behaviors after the course**
  Evidence of continuing interest in (or learning about) course-related topics;
  Evidence of taking additional chemistry courses, realizing that for non-majors, there may be few options.
- **Informal evidence of continuing interest in chemistry**
  Conversations, correspondence, etc.

Discussion: *These forms of evidence are influential, in some cases highly so.* One indication is that instructors (*e.g.*, those attending workshops) use the existing data (*e.g.*, from the workshop presenters) to consider whether to learn more about or to use the curriculum. Testimonials from satisfied instructors have similar influence. Conversely, evidence that instructors (or their students) are <u>not</u> responding well to the approach can turn instructors away from teaching with *Chemistry in Context*.

These forms of evidence are limited in applicability. They carry weight primarily for instructors who currently use the approach or are seeking to design a chemistry course anchored in real-world issues (*e.g.,* a general education requirement). They are unlikely to influence others.

These forms of evidence have gaps. Most instructors do not collect data on student attitude. Data on student behaviors after the course is similarly non-existent. Evidence of continuing interest in chemistry most likely exists in anecdotal form (email, conversations), but is not catalogued and disseminated. Systematically collecting and disseminating forms of evidence such as these, even if after the fact, would be useful to document project outcomes.

B. Student Knowledge of Chemistry

This evidence pertains to **Goals #3**, **#4** and **#5** (science literacy, citizenship, informed choices). Although the evidence tends to be more formal than in the previous section, it still is collected with widely ranging practices and resides locally. The forms of evidence include:

- **Direct assessment of knowledge/skills acquired in the course**
  Student performance on class quizzes, exams, and laboratory experiments. Skills as demonstrated by class activities (*i.e.*, projects, class debates, position papers, civic engagement with issues, poster sessions).
- **Student-centered course survey instruments**
  Surveys with questions about how well different aspects of the course helped *the students* to learn. See sample data in Appendix E.
- **Course-level data**
  Class completion rate, class attendance, and number of attempts to complete the course.

Discussion: Again, *these forms of evidence are influential, but have limited applicability.* The analysis from the previous section applies here as well.

Note #1: Instructors of introductory chemistry courses use learning objectives in many different ways. *Chemistry in Context* is no exception. For example, instructors may (a) use the end-of-chapter learning objectives in whole or in part; (b) write their own learning objectives; (c) create larger, more philosophical goals of the course; (d) employ a combination of all of these; or (e) pay only minimal attention to learning goals/objectives. Although practices with learning goals vary, it is standard practice to assess student knowledge regularly via quizzes, tests, and final exams. *Chemistry in Context* also includes opportunities for instructors to assign essays, position papers, class debates, posters, class presentations and other more broadly based assessment tools. This type of summative work is an excellent match for these broadly based learning goals.

Note #2: Since the origin of the project, the Student Assessment of Learning Gains ("The SALG") became available. It is a web-based student-centered instrument that allows students to report both the extent to which particular aspects of the course have helped them learn and how much they have learned about specific topics.[22] Although this assessment tool appears tailor-made to give evidence that relates to the goals of *Chemistry in Context*, to date only three instructors appear to have used the SALG.[23] Sample data for one appears in Appendix E.

C. Larger Outcomes of the Project

This evidence pertains to **Goals #6** and **#7** (project adoption and broader influence). Examples include:

- **Similar course/curriculum goals articulated by others**
  Evidence that other projects are responding to the same needs for undergraduate non-science majors, using the same or closely related goals for student learning
- **Widespread use of the text**

Sales of the text as reported by publisher

- **Similar textbooks created by others**
  Existence of other chemistry texts taking a context-based approach.
  Evidence of context-based projects in other fields.
- **Translation of the text into other languages**
  Reports from the publisher of editions in other languages.

Discussion: *This evidence varies in quality and availability*. For example, evidence of other context-based courses is of variable quality and not readily available. This evidence resides in many places (conference presentations, college-wide curriculum goals, final reports to funding agencies, journal articles). In contrast, evidence for the use of the textbook is of high quality. It includes: (1) the book is in its sixth edition with the seventh edition in preparation; (2) it has been translated into Korean and Chinese, with contracts pending in Arabic, Japanese, and Spanish; (3) the publisher reports it has been and continues to be the most widely adopted text in its market. The sixth edition, on the shelves since January 2008, has more than 250 adopters. It also is used in a dozen colleges/universities in Canada and in several Spanish-speaking countries. Sales of the book, as reported by the McGraw-Hill Company, have risen steadily from the first edition.[1]

Edition	1st year sales
1st	6,012
2nd	N/A
3rd	8,671
4th	10,227
5th	22,653
6th	23,000 (est)

O*nly to the extent that the evidence is known can it motivate instructors (plus their curriculum committees and their administrators)* to adopt the curriculum. Instructors, especially those at smaller institutions, do not travel to national meetings or workshops and hence are likely to have little, if any, knowledge of these forms of evidence. Very little has been published about *Chemistry in Context* in peer-reviewed journals. Knowledge of the book's sales record and its translation into other languages is known by very few users.

Even so, *Chemistry in Context* established a tradition that other national curriculum reform endeavors in the past decade followed. For example, two projects, both funded by the NSF, cite *Chemistry in Context* as a precedent. The first was the *ChemLinks* and *Modular Chemistry course (MC^2)* consortia[24]. This curriculum for science-majors used chemistry modules based on real-world topics such as water treatment, global warming, and the ozone hole. Brock Spencer (Beloit College), one of the PIs, acknowledged the important role that Truman Schwartz, the first Editor-in-Chief of *Chemistry in Context*, played in shaping the outline of the *ChemLinks* project. The second in 2000 was *SENCER*, *Science Education for New Civic Engagements and Responsibilities*.[25] David Burns and Karen Oates, the PIs, credited *Chemistry in Context* as an earlier project that engaged students in learning science through real-world issues. *SENCER* Model courses include Energy and the Environment (2002 Model Course), Global Warming (2003 Model Course), and Water Power (2007 Model Course).[26]

As of 2007, a competitor for *Chemistry in Context* appeared in the non-science major textbook market: *The Chemistry of Everything*.[27] The author's description of this book reads: "Through innovative themes and fascinating applications, the text provides an engaging introduction to chemistry for non-science majors. Chemistry content is blended with these compelling applications, striking an amazing balance."[28] This is exactly the proof of success for which the ACS initially had hoped; namely, that others would follow the lead.

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[1]Tami Hodge, the Senior Sponsoring Editor at McGraw-Hill for *Chemistry in Context*, kindly provided these figures. The first year sales for a new edition are the best indicator of how many students are using the book, as the units sold in later years decrease because of the used book market.

VI. A Larger Context for Establishing Evidence

This section addresses the final question posed to its author; namely, "How important has the quality of evidence been in influencing or guiding the widespread uptake of a promising practice?" Underlying this question is perhaps the idea that evidence of student learning largely is considered the gold standard in driving curriculum reform. However, while such evidence is necessary, it may not be *sufficient*. This final section examines the wider context in which the project resides with an eye towards identifying additional factors that may be at work.

The forms of evidence listed for *Chemistry in Context* in the previous sections relate to student learning, student attitudes, and to the larger outcomes of the project. These forms of evidence are compelling to instructors who use or are inclined to try the approach. But in the case of *Chemistry in Context*, such evidence is not systematically collected and categorized. For the most part, the evidence resides locally. The most common mode of dissemination for this evidence is presentations at regional and national meetings and workshops for instructors. Given the current state of the evidence, *it is difficult to make a case that this evidence, in and of itself, has been responsible for the success of the project.*

If not solely the evidence, what else could be driving the uptake? For *Chemistry in Context*, two additional factors appear relevant: (1) the influence of professional societies; and (2) the urgency of issues in our communities, regions, and global communities that require knowledge of science.

Interestingly enough, both factors were observed at play by the author in her recent trip to China on the occasion of the release of the new Chinese-language edition of *Chemistry in Context* at the 26th Congress of the Chinese Chemical Society (CCS). The book release was a collaborative effort of two professional societies, the CCS and the ACS. In a dramatic ceremony, leaders from both societies unveiled the book and highlighted its contributions. Bruce Bursten, the 2008 President of the ACS, spoke these words at the opening session: "As ACS president and a world citizen, I passionately believe we need to orient our future collaboration efforts to assure that chemistry contributes to solving the world's most vexing current problems relating to sustainability and energy, food, and water."[29] Other speakers at the conference named the need for citizens literate in science who could apply their knowledge to real-world issues such as water and air quality. Over 300 copies of the text were sold to those attending.

A. Professional Societies

The actions of professional societies carry intrinsic weight. These societies represent large numbers of people; they have a collective voice and authority. In the case of *Chemistry in Context*, the imprimatur of the American Chemical Society, the largest society of its kind in the world, surely played a role in its early success.

Another example is the American Association of Colleges & Universities (AAC&U), an organization with over 1100 member institutions. In 2005, the AAC&U launched the *LEAP* initiative, *Liberal Education for America's Promise.* This initiative set forth learning outcomes for preparing undergraduates to meet the challenges they face in today's world. One learning outcome was "Knowledge of … the physical and natural world … focused by engagement with big questions, both contemporary and enduring."[30] With this statement, the AAC&U gave importance to exactly the type of contemporary and enduring issues on which *Chemistry in Context* is based. The LEAP initiative may turn out to be a factor influencing the current rate of uptake for *Chemistry in Context*.

Thus, gathering evidence about the influence of professional societies could well inform the dissemination and uptake of curriculum reform projects. For example:

- Evidence for member involvement (on the individual, departmental, or institutional level) with professional societies, and the outcomes of this involvement.
- Evidence from case studies about the circumstances under which professional societies have influenced change.
- Evidence from ethnographic studies of faculty, administrators, and professional society personnel. For example, what are the areas of professional society influence? How do all the parties involved perceive this influence?
- Evidence for pushback. For example, chemists who write textbooks have voiced concern that their professional society is competing with them. Similarly, faculty members push back against professional organizations that intrude on their authority in the classroom. What is the nature of this pushback and how does it affect all parties involved?

B. Urgent global issues

Chemistry in Context resides in a context: the real-world. This context includes communities of people with local, regional, and global concerns. This context is rich with issues that are complex, inherently interdisciplinary, and that lack easy answers.

In the early years of the *Chemistry in Context* project, our nation was in need of citizens who could make informed decisions, based on their knowledge of science, to address real-world issues. This same need still exists. Today we also need citizens who have the skills and attitudes that relate to sustainability. See, for example, the list of skills articulated by the Washington Center (Appendix D).

Evidence already exists that scientists have recognized both the urgency of the issues and the need for an informed citizenry. Professional societies (see previous section) are one such group. For example, the theme of the upcoming 2009 national meeting of the American Association for the Advancement of Science is "Our Planet and its Life: Origins and Futures." The description of the theme contains compelling language:

> *The reference to "our" planet in the theme is intentionally presumptive. In a single human generation our species' effect on Earth's climate has been revealed. The warming of our planet is unequivocal, and human activities are a primary cause. Change in climate is now evident at regional scales in precipitation patterns, in storms, in diminished land and ocean ice, and in rising sea level. …*
>
> *Within the next few human generations, the effect of these climate changes could put the survival of many species at risk. The natural processes so astutely intuited by Darwin can now be swamped by the actions of a single species….*
>
> *But we need not let this be the future that is realized. Just as advances in technology and advances in science have led both to our current condition and our understanding of its implications, the wise use of technology and scientific understanding can allow us to select a different future.*[31]

Similarly, the theme for the upcoming 238th National Meeting of the ACS to be held in Washington, DC, will be "Chemistry and Global Security: Challenges and Opportunities." A sub-theme of the meeting will be "Chemistry of CO_2 and Climate Change."

> *Expansion of the global economy and enhanced global travel and communications have resulted in many opportunities for the chemical enterprise. However, this global expansion has also presented us with some challenges through the inappropriate use, and even misuse, of technologies, in some cases resulting in unacceptable solutions. This has led to threats to the global security; for example through the chemistry of CO_2 and climate change, chemical and biological terrorism, a shortage of energy reserves, the need for alternative sources of energy, and antibiotic-resistant microorganisms, and many more. Yet these challenges also present opportunities for solutions, discovery, creativity and imagination to make the world a better and safer place in which to live, not only for our generation but also for those to come.*[32]

To what extent is this need for educated citizens a factor in driving the success of the project? An answer to question, one grounded in research, would appear to be highly relevant to this project. Gathering evidence about the influence of real-world issues on our thinking as members of a discipline, on our departments, on our curriculum, and on our students could well inform the dissemination and uptake of *any* curriculum based in complex real-world challenges, ones not amenable to easy or quick solutions.

Concluding Thoughts

From its outset, the *Chemistry in Context* project has been concerned with student learning. It was important to the original project architects that student learn chemistry and, more generally, that they learn the habits of mind necessary to be an informed citizen in today's world. This White Paper took student learning as its starting point and named important learning goals for non-science majors. The paper also offered the reader an analysis of the existing forms evidence that support student learning, it commented on the weight that these forms of evidence are likely to carry, and it highlighted gaps in the evidence.

However, to the surprise of its author (and perhaps to the reader as well), the process of analyzing the evidence led to a new understanding. Although the evidence of learning outcomes is strong, this evidence alone is unlikely to account for the uptake of *Chemistry in Context*. The previous section commented on this finding at length.

It is worth stating what perhaps has been hidden in plain sight. <u>This project lies squarely at the intersection of a professional society and the real world</u>. Without the American Chemical Society, this project would not have been launched. And without the pressing issues of the real-world, there would not have been such a compelling context in which to launch it.

It also is worth making explicit an underlying rationale for naming goals and for addressing the forms of evidence that support these goals. Ultimately, such evidence is desirable because it plays an important role either <u>in driving change</u> in higher education or <u>in validating change</u> in the eyes of instructors and administrators *after* the uptake of a new curriculum or pedagogy actually has occurred.

If producing change that benefits our students, our disciplines, and our world indeed is the intended outcome of producing evidence, this White Paper points to the fact that we must gather additional evidence as to what drives change. Professional societies and real-world issues are two additional key factors to consider. If ultimately we seek changes in what content our students learn and in the pedagogies with which they are learning this content, only at our own peril can we ignore the roles that professional societies and real-world issues play in making these changes a reality.

Acknowledgments

It takes a village to write a textbook. Many members of this village not only have contributed to the creation of this document and critiqued it, but also have been an inspiration to its author for many years. These include previous Editors-in-Chief (Truman Schwartz, Conrad Stanitski, and Lucy Eubanks) and past and current members of the author writing teams. These also include leaders at the ACS, especially Education Division Directors Sylvia Ware and Mary Kirchhoff, together with key senior support staff including Jerry Bell, Terry Nally, Christine Brennen, Marta Gmurczyk, and Corrie Kuniyoshi. The author also acknowledges the determination and wisdom shown by her co-PIs on the NSF project *Mobilizing STEM for a Sustainable Future*: Jean MacGregor, Susan Millar, and Elaine Seymour. This grant, funded by the NSF in 2007, is to mobilize the significant work already accomplished in STEM reform so that changes take place at a speed that better matches the urgency of the issues in our world that we face today.

Appendix A

Chemistry in Context, 6th edition, ©2009
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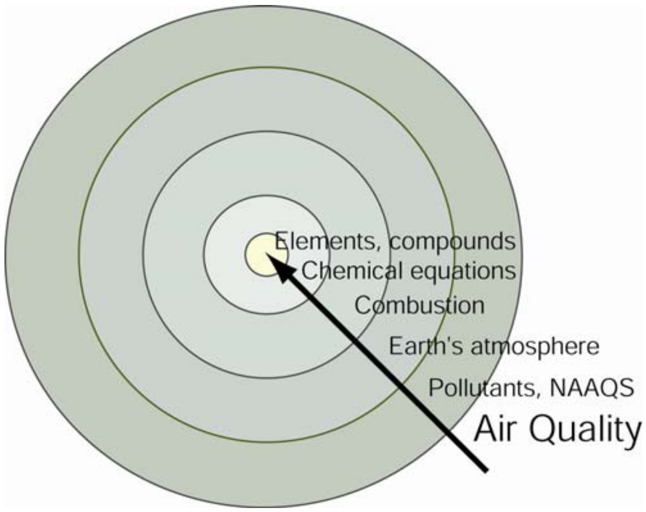
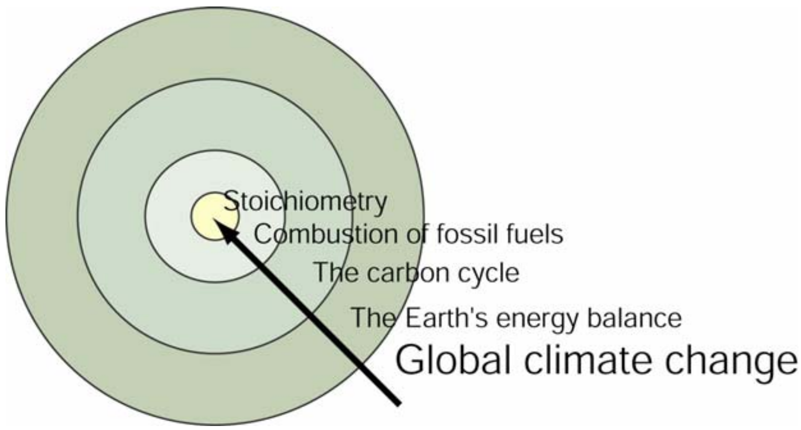
Appendix B
Representations of the instructional pathway

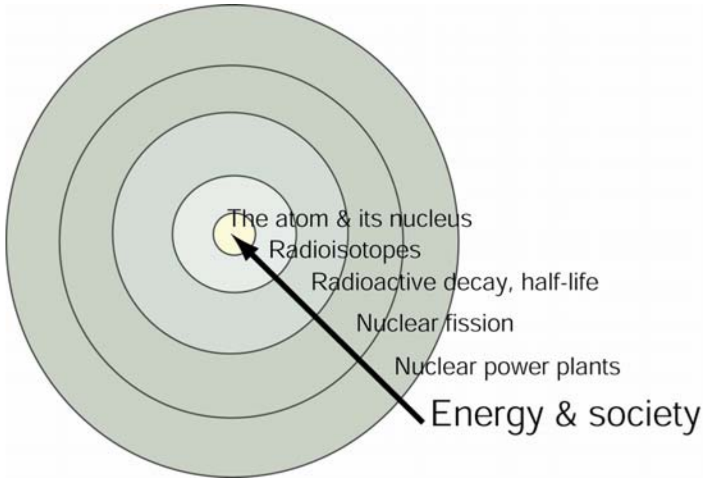
1 The Air We Breathe



3 The Chemistry of Global Warming



7 The Fires of Nuclear Fission



Appendix C

Chemistry in Context, 6th Edition

> "Following in the tradition of its first five editions, the goal of *Chemistry in Context*, sixth edition, is to establish chemical principles on a need-to-know basis within a contextual framework of significant social, political, economic, and ethical issues. We believe that by using this approach, students not majoring in a science develop critical thinking ability, the chemical knowledge and competence to better assess risks and benefits, and the skills that can enable them to make informed and reasonable decisions about technology-based issues.
>
> … In this book, chemistry is woven into the web of life. The chapter titles of *Chemistry in Context* reflect today's technological issues and the chemistry principles imbedded within them. Global warming, acid rain, alternative fuels, nutrition, and genetic engineering are examples of such issues. To understand and respond thoughtfully in an informed manner to these vitally important issues, students must know the chemical principles that underlie the socio-technological issues. This book presents those principles."

Preface
Lucy Pryde Eubanks
Senior Author and Editor-in-Chief
January 2008

Appendix D

WASHINGTON CENTER
FOR IMPROVING THE QUALITY OF UNDERGRADUATE EDUCATION

"CURRICULUM FOR THE BIOREGION" INITIATIVE SUSTAINABILITY LEARNING OUTCOMES[33]

SUSTAINABILITY SKILLS

- Ability to listen and hear w/ intellectual openness, outside of your usual ways of thinking
- Ability to be sensitive to cross-cultural perspectives
- Ability to work collaboratively in groups as an essential communications skill
- Ability to use and apply systems thinking
- Ability to think laterally, synthesize, and connect the dots – as or more important than current emphasis on analysis
- Ability to reflect on one's values and habits, and to recognize that one's personal choices can affect sustainability
- Ability to translate understanding to action and commitment; using change-agent strategies
- Ability to cope with complexity by examining complex problems, and by hearing other perspectives.
- Skills of observation and empiricism – observing outside your usual way, observing deliberately
- Critical thinking – examining what you know and how you know it
- Ability to practice acts of civic responsibility: taking small, practical steps, walking your talk
- Ability to recognize and evaluate an injustice: moral decision making
- Ability to reflect on knowledge, values, and commitment through a variety of media, including artistic expression

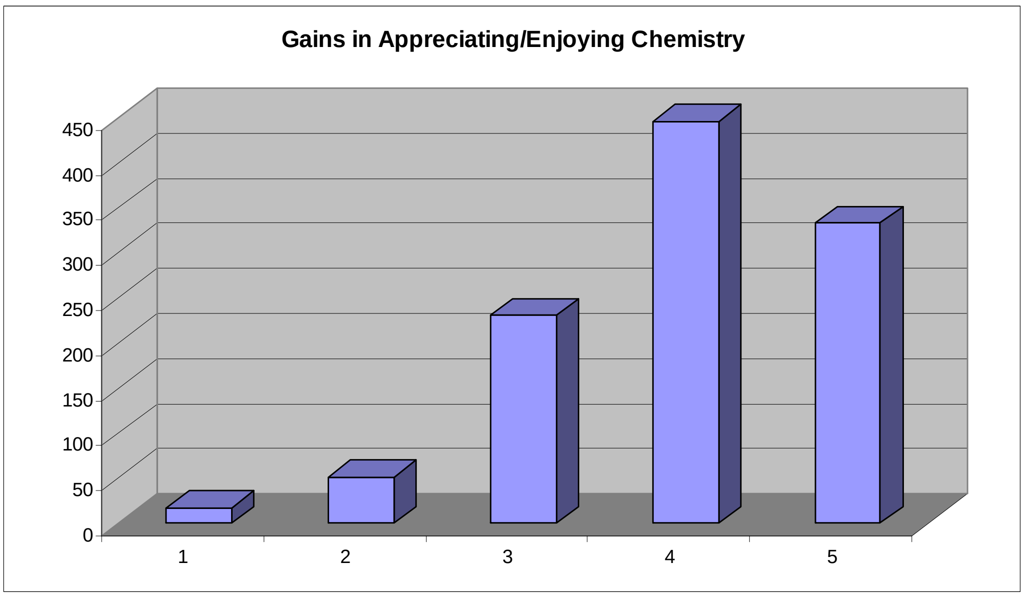
Appendix E
Sample evidence from course survey instruments

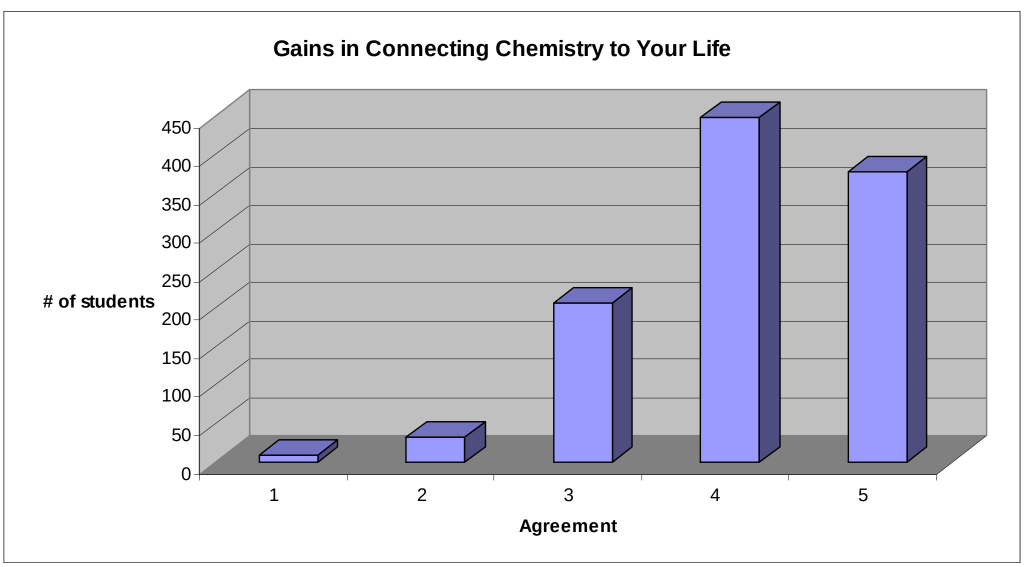
A. The Student Assessment of Learning Gains (the SALG)

This data (n>1000) is compiled over the past 5 years semesters at the University of Wisconsin-Madison. (Instructor = Cathy Middlecamp)

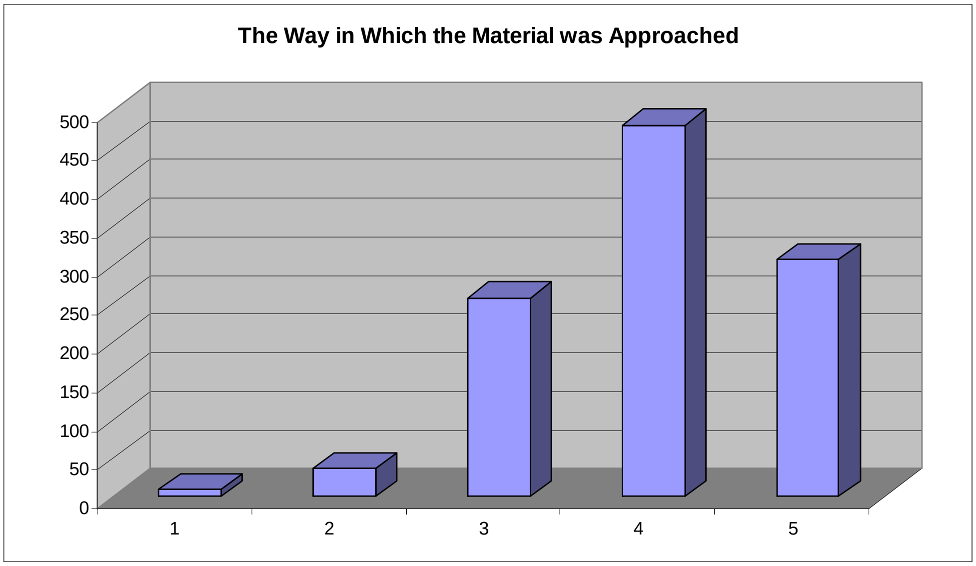
Q#1 To what extent did you make gains in any of the following as a result of what you did in this class?

Responses **1 Not at all** **2 A little** **3 Somewhat** **4 A lot 5 A great deal**





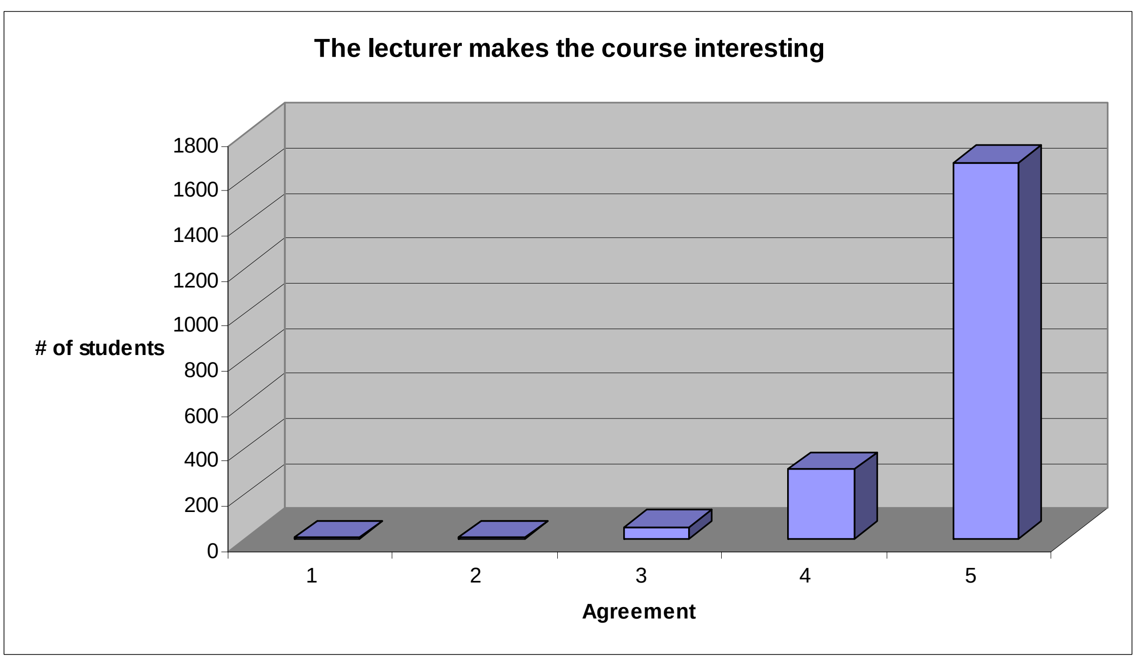
Q#2 How much did each of the following aspects of the class help your learning?



B. Department evaluation form (an instructor-centered instrument)

This data (n>2000) is compiled over the past decade at the University of Wisconsin-Madison. (Instructor = Cathy Middlecamp)

SCALE: 1= strongly disagree, 5= strongly agree



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[2] American Chemical Society, *Chemistry in the Community*, 5th Ed., W. H. Freeman and Company, 2006.

[3] *The Liberal Art of Science: Agenda for Action*, AAAS Project on Liberal Education and the Sciences, 1990.

[4] A. Truman Schwartz, Diane M. Bunce, Robert G. Silberman, Conrad L. Stanitski, Wilmer J. Stratton, and Arden P. Zipp, *Chemistry in Context*, 1st Ed., Dubuque, IA, William C. Brown Publishers, 1994.

[5] To help them recognize and meet these challenges, authors provide support via workshops held at regional and national meetings, yearly short courses (ended in 2006), and instructional resources on the textbook web site.

[6] Elaine Seymour and Nancy Hewitt, *Talking About Leaving, Why Undergraduates Leave Science*, Westview Press, Boulder, CO, 1997.

[7]Sheila Tobias, *They're Not Dumb, They're Different*, Research Corporation, Tucson, AZ. 1990.

[8] Consider also this conversation stopper at a party, one well known to many who teach chemistry, calculus, and physics. "What do you do?" "I teach chemistry." [Pause] "Oh. I hated my chemistry course."

[9] A. Truman Schwartz, et al., op. cit.

[10] Lucy Pryde Eubanks, Catherine Middlecamp, Carl Heltzel, and Steve Keller, *Chemistry in Context*, 6th Ed., Dubuque, IA, McGraw–Hill, 2009.

[11] A. Truman Schwartz, et al., op. cit.

[12] Ibid.
[13] Ibid.
[14] Ibid.

[15] Ronald A. Archer, Foreword to *Chemistry in Context*, 1st Ed., 1994.

[16]A. Truman Schwartz, et al., op. cit.

[17] William F. Carroll, Jr., Douglas J. Raber, *The Chemistry Enterprise in 2015*, American Chemical Society, 2005.

[18] One of the most widely used definitions of sustainability is: "Meeting the needs of the present without compromising the ability of future generations to meet their needs," taken from the *UN Report on the World Commission on Environment and Development* ("*Our Common Future"*).

[19] A comprehensive set of "sustainability skills" have been developed by the Washington Center for Improving Undergraduate Education. These are excellent and this project will make use of them. See Appendix D.

[20]A. Truman Schwartz, et al., op. cit.
[21] Ibid.

[22] Student Assessment of Learning Gains, www.salgsite.org, accessed June 2008. "The SALG site currently has 434 instructors, 63 instruments, and 1612 student responses. The Student Assessment of their Learning Gains (SALG) instrument was originally developed in 1997 by Elaine Seymour while she was co-evaluator for two National Science Foundation-funded chemistry consortia (ChemLinks and ModularCHEM)."

[23] Personal correspondence from Sue Lottridge, SALG administrator. Although the SALG data are confidential, Sue was able to report that three courses had a title identifiable as a Chemistry in Context course.

[24] ChemConnections, 2004, George Lisensky and Marco Molinaro, ed., chemistry.beloit.edu, (accessed June 2008).

[25] Science Education for New Civic Engagements and Responsibilities (SENCER), www.sencer.net (accessed June 2008).

[26] SENCER Model Courses, www.sencer.net/Resources/models.cfm (accessed June 2008).

[27]Kimberly Waldron, *The Chemistry of Everything*, 1st Ed., Pearson, Upper Saddle River, NJ, 2007

[28] *The Chemistry of Everything*, www.pearsonhighered.com/educator/academic/product/0,3110,0130085227,00.html (accessed June 2008).

[29]Remarks by Bruce Bursten (ACS President) at the opening session of the 26th Chinese Chemical Society Congress, Tianjin, China, July 13, 2008.

[30] LEAP Essential Learning Outcomes, www.aacu.org/leap/vision.cfm (accessed June 2008).

[31] AAAS Annual Meeting, 12-16 February, 2009, www.aaas.org/meetings/2009/program/theme/ (accessed June 2008).

[32] Correspondence from Richard Love (Manager, Programming and Technology) to ACS Division Program Chairs, June 25, 2008.

[33] These sustainability "big ideas, skills, and habits of mind" came out of a brainstorming conversation about outcomes for student learning, in which 120 faculty members participated at the Washington Center's "Teaching for a Sustainable Future" conference in November 2006. At a Washington Center Curriculum Planning Retreat in Spring 2007, an inter-institutional, interdisciplinary faculty working group honed the dozens of suggested outcomes to this list.