

Contemporary Moral Problems in Chemistry: Effect of Peer Presentations on Students' Awareness of Science and Society Issues

Amy J. Phelps
Middle Tennessee State University
Murfreesboro, TN 37132



Harold B. White III,* Steven D. Brown, and Murray V. Johnston

Department of Chemistry and Biochemistry, University of Delaware, Newark, DE 19716; *halwhite@udel.edu

The origins of and solutions to many of today's major global and societal challenges lie in the realm of chemistry. Curricula (1, 2) and textbooks (3) for undergraduate chemistry majors justifiably put heavy emphasis on basic understanding of chemical concepts and skills but rarely or only loosely connect them to social issues and practical applications as is often done in textbooks for chemistry courses for nonmajors (4). Furthermore, instructors often feel uncomfortable devoting valuable classroom time in the majors' curriculum to topics not related to their content expertise. However, chemistry graduates can (and have a responsibility to) make important contributions in the public discussion of how to deal with certain science and society issues. Recent graduates may find themselves dealing with issues that involve significant social and political dimensions they never anticipated or appreciated. In our experience, they are poorly prepared to provide relevant information in structured arguments to address these issues.

In an attempt to inform and sensitize our students to societal issues relating to science in a setting that emphasizes oral and visual communication, we introduced a new format to the fall semester of a required one-credit, pass-fail chemistry senior seminar course for chemistry and biochemistry majors (5). In this capstone course (dubbed Contemporary Moral Problems in Chemistry by a student), small groups of students each study a different societal issue posed as a proposition, such

as, "acid rain can be prevented without compromising industrial output". Students defend or refute the proposition before the rest of the class on an informative Web site and in a 15-minute group presentation. Surveys at the beginning and again at the end of the course on these and other propositions enabled us to assess whether the peer presentations had a significant impact on classmates' positions on these topics compared to propositions that were not presented. We have analyzed pre- and postcourse responses of 250 students in eleven sections of the course over six years (1997–2002).

Our data show that few chemistry and biochemistry seniors have given much thought to social issues where information from their disciplines might be helpful in understanding those issues. As a consequence, a relatively high proportion of these students are unaware or indifferent to these issues. However, that proportion often drops significantly for those issues that peers have presented to the class and argued for a particular position.

Experimental Design

On the first and last days of class each fall semester, students in the chemistry senior seminar complete a survey anonymously indicating their position—agree, disagree, don't know, don't care—on propositions relating to science and society. List 1 identifies the 78 issues the propositions addressed.

List 1. Societal Issues Addressed by Propositions in a Chemistry Senior Seminar

Legal and Illegal Drugs

Performance Enhancing
Thalidomide
FDA Regulations
Drug Discovery
Ritalin Overuse
RU486 Approval
HIV Drug Pricing
Reversibility of Addiction
Caffeine Safety
Anabolic Steroids

Food

Natural versus Organic
Aspartame Safety
Vegetarian Diets
Genetic Modification
Food Irradiation
Olestra Safety
Mad Cow Disease
Neutraceuticals
Fertilizer Production
Mega Vitamin C
Dietary Salt

Health

Cell Phone Risks
Antibiotics in Feed
Silicone Implants
Bottled Water
Yearly Mammogram
Estrogen Therapy
HIV Cure
Human Genome Use
Cancer Cure
Lupus and Asthma Causes
Cigarette Use

Energy

SUV Restrictions
Oil Conservation
Nuclear Power
Paper versus Plastic
Fuel Efficient Cars
Hybrid Cars
Aluminum Recycling

Public Policy and Ethics

Chemical and Biological Warfare
Genetic Screening
Screening for Criminality
Animal Cloning
Stem Cell Research
Water Fluoridation
Water Chlorination
Science Teachers' Salaries
Global Warming
NIH and Malaria Research

Science and Research

Image of Science
Applied versus Basic
Animal Research
Secrecy
Limits
Objectivity
Gender Representation
Prohibited Science
Religious Beliefs

Environmental Pollution

Acid Rain
Antiknock Gasoline
DDT
Dioxin
Atmospheric Particulates
Greenhouse Gases
Hormone Disruptors
Mercury Emissions
Lawn Care Chemicals
Ozone Layer
Green Chemistry
Asbestos Removal
Chlorinated Solvent Use
Superfund Site Cleanup
Insecticide Use

Miscellaneous Topics

Creation versus Evolution
Human Evolution
Evolution and Medical Practice
Human Rationality
Research versus Teaching

Students complete the surveys in about 20 minutes. Although the particular set of propositions and their precise wording varied to some extent each year, there was significant overlap from year to year with 14 proposition topics used all six years. Of these, 11 were repeated verbatim. The full list of propositions appears in the Supplemental Materials.^u

Each student separately requested and rank-ordered three of the propositions he or she would like to study in greater depth and present to the class. From the requests, we created groups of usually three students having interest in particular propositions. Typically, more than 70% of the students got their first or second choice. Rarely did we have to assign a student to a group whose topic was not on his or her original list. Occasionally we moved students into the other section of the course to accommodate requests. This procedure meant that the oral presentations later in the semester likely would come from peers who had some motivation to learn more about a topic and present it well.

In the last month of the semester, between 9 and 13 different propositions of the 36 to 42 available each year were presented orally. The 24 to 32 propositions that were not presented served as negative controls in this study.

Starting in 1998, all students formally reviewed, with written summaries sent to the instructor, several Web sites produced by students in former classes, as described previously (5). This exercise early in the semester served to set quality standards for Web site content and to expose students to additional topics. After researching their topic, each group was expected to produce an outline or concept map of that topic as a prelude to creating a Web site. Students completed an informative Web site presenting their position at least a week before the series of seminars began. The Web sites were peer-reviewed by students from both sections of the course, revised, and peer-evaluated by a different subset of students by the end of the course.

All group members participated in a 15-minute presentation followed by a 10-minute question and answer period with two presentations made in a 50-minute period. Prior to 2000, presentations were given using overhead projectors; thereafter, PowerPoint presentations were expected. Students

who did not have class conflicts were expected (1997, 1999, and 2002) or encouraged (1998, 2000, 2001) to attend presentations given in both sections, which were scheduled in consecutive time periods in the same room. In addition to classmates, the audience included several unannounced guests ("wild cards") who were invited by the instructors, based on the guests' expertise (5). On the last day of the course, students again filled out the survey anonymously indicating their positions on the multiple propositions. The total postcourse response was near 94% of the initial number of responses over the six-year study.

Student survey responses at the end of the course were compared to the initial responses for each proposition for each section and year of the course and evaluated for significant changes ($p \leq 0.05$) by χ^2 analysis (6). Supplementary materials available online include the statistical analysis of the students' pre-post responses to every proposition by section and year—all 350 data sets collected over six years.^w The data presented below are selected to illustrate points supported by many more examples available online.

Results

Effect of Peer Presentations on Pre-Post Survey Responses

Table 1 shows that changes in students' responses at the end of the course relative to students' initial responses occurred predominantly and with very high statistical significance for those propositions that were presented orally by peers during the semester (27 out of 63). The number of statistically significant pre-post differences among topics that were not presented orally (6 out of 171) is less than the 8 or 9 expected by chance alone at the $p = 0.05$ level. This pattern of significance overall was replicated ($p < 0.002$) in five of the six years of the study.

Stability of Student Positions on Societal Issues in the Absence of Intervention

Over the course of this study, 14 of the 78 proposition topics were used in all six years. Of these, the wording remained unchanged for eleven. These eleven are listed in Table

Table 1. Change in Students' Positions on Societal Issues as a Function of Peer Presentations

Year	Number	Orally Presented Propositions		Propositions Not Presented		p-Value
		Change Not Significant	Significant Change	Change Not Significant	Significant Change	
1997	36	4	5	25	2	1.57×10^{-3}
1998	36	6	6	23	1	1.06×10^{-3}
1999	40	7	3	30	0	1.81×10^{-3}
2000	40	6 ^a	7	26	1	2.05×10^{-4}
2001	40	8	1	30	1 ^b	3.39×10^{-1}
2002	42	5	5	31	1	2.18×10^{-4}
Total	234	36	27	165	6	1.71×10^{-14}

^aTwo sets of data were significant for the section in which they were presented, but not for the class as a whole. ^bThis proposition was developed for the class by one instructor as an illustration early in the semester. See proposition 1 in Table 3 and related discussion.

2 and provide a useful subset to determine whether student responses differ from year to year. For none of these eleven propositions were there any significant differences ($p \leq 0.05$) in the pattern of the students' initial responses over the six years, nor were there time-dependent trends apparent in the initial responses. This result suggests that the population of students taking the course remained fairly similar in their awareness of and attitudes toward these science and society issues from year to year. Interestingly, differences in initial responses between the two sections in the same year were sometimes quite different suggesting that cohorts of students with similar positions schedule classes together or that students' societal attitudes are in some way reflected in their choice of instructor.

Of the eleven unaltered propositions presented in all six years of this study, seven were never selected by students for

oral presentation. Other than proposition 1 in Table 2, which will be discussed below, in only one instance (proposition 3 in 2002) did the final response barely reach significance ($p = 0.045$) compared to the initial response in a particular year. However, when the final responses for all six years are combined for each proposition and compared to the corresponding combined initial responses, the final responses all show significant or near-significant changes. This finding suggests that other topics presented in the course or the increased social awareness generated by the course contributed to small but systematic changes that were not apparent from the response of the smaller number of students in a single year. In particular, the overall number of undecided responses declined for every proposition listed in Table 2. This is a fairly general pattern that is seen with most other propositions as well, whether presented or not.

Table 2. Distribution of Students' Responses to Survey Propositions over the Six Years of This Study

Proposition Statement	"Agree", %	"Disagree", %	"Undecided", %	"Don't Care", %	Pre-Post p -Values
1. Without the industrial chemical reduction of atmospheric nitrogen, starvation would be rampant in third-world countries.	10.0 23.3	14.1 18.4	70.7 53.9	4.0 3.9	0.00000804
2. Secrecy has no place in academic research done in collaboration with the chemical industry.	29.7 39.6	39.4 40.4	28.9 18.3	2.0 1.7	0.039
3. Opportunities for women in chemistry are limited relative to those for men.	18.3 29.1	57.0 53.9	21.9 15.4	2.3 2.6	0.032
4. In most cases there are alternatives to using animals in research.	32.9 37.2	41.0 44.9	22.5 17.1	3.6 1.3	0.141
5. The dangers of asbestos used for tiles and insulation in buildings are insufficient to warrant the high cost of its removal.	13.1 19.7	68.0 60.7	18.9 18.0	0.4 1.7	0.132
6. Fossil hydrocarbons are too valuable as a source of recyclable plastic to be burned for fuel.	18.2 24.2	24.3 29.7	53.9 43.6	4.1 2.5	0.082
7. There is an objectively correct answer to any question relating to chemistry.	14.8 21.8	63.6 64.8	21.2 12.3	0.4 1.3	0.019
8. Drinking water should be treated with hydrogen peroxide rather than chlorine.	8.2	24.1	64.1	4.5	N/A
9. Nuclear power generation is the only viable long-term solution to the energy problem.	9.7	64.3	25.0	0.4	N/A
10. The chemical industry took responsible action when confronted with evidence that the ozone layer was being depleted by fluorocarbons.	41.0	18.5	38.2	2.4	N/A
11. Taking anabolic steroids for body building is in principle no different from administering growth hormone to persons with inherited dwarfism.	8.9	75.0	13.3	2.8	N/A

Note: Numbers in bold are initial student responses ("pre" positions); the numbers underneath are final student responses ("post" positions). Final responses are not provided for propositions 8–11: peers' oral presentations of these in one or more prior years might have influenced final responses. There were no significant differences among years in initial responses for any of these propositions.

Influence of Visual Conceptualization on Student Responses

Proposition 1, which showed a highly significant pre-post course change in responses when summed over six years, is a special case. Every year, this proposition has a consistently high percentage of initially undecided student responses (~70%), suggesting that the students were unaware of or did not understand the issue. Starting in 1998, one of the instructors (HBW) used this topic early in the course in his sections to illustrate how one might construct a case support-

ing or opposing a proposition. While there were consistent but nonsignificant changes in initial versus final student responses that accumulated for several years, in 2001 there was a significant pre-post change in the class response ($p = 0.02$). This change coincided with a formal presentation by HBW and the distribution of a concept map that connected topics related to proposition 1, such as the Haber-Bosch process, biological nitrogen fixation, fertilizers, food production and consumption, amino acid requirements, population growth, and other chemistry topics relevant to chemical applications in agriculture, as shown in Figure 1.

Figure 1. Concept map for the proposition: without the industrial chemical reduction of atmospheric nitrogen, starvation would be rampant in third-world countries.

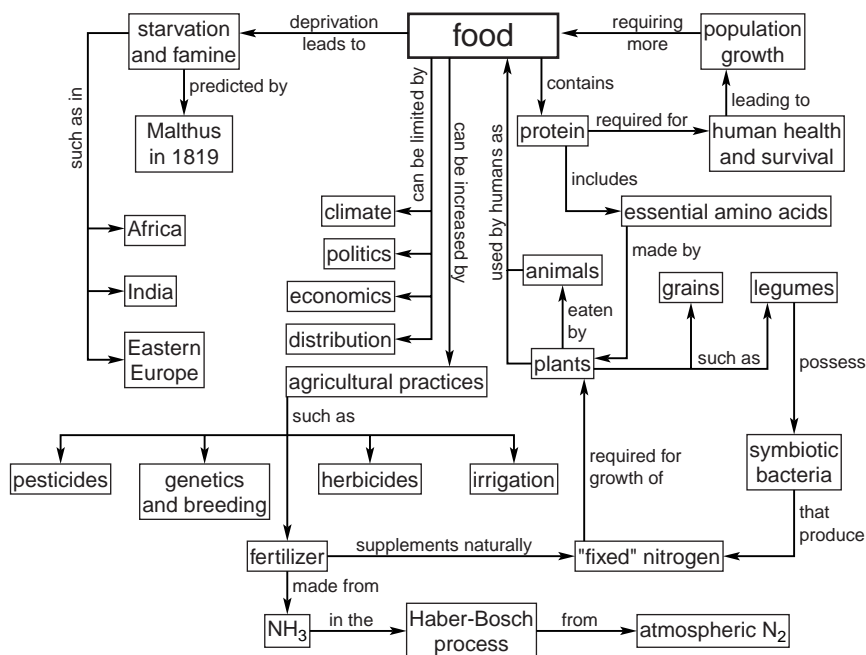


Table 3. Influence of Advocacy on Students' Final Responses to a Proposition Concerning Nuclear Power

Year	Advocacy Position	"Agree"	"Disagree"	"Undecided"	"Don't Care"	Pre-Post p -Values
1997	Opposed	5 2	32 34	10 9	0 0	0.505 ^a
1998	No presentation	6 8	21 25	15 10	0 0	0.444
1999	Supported	7 19	22 13	8 2	0 1	0.0062
2000	No presentation	3 8	39 34	8 6	1 1	0.413
2001	No presentation	2 6	25 18	6 7	0 2	0.157
2002	Opposed	1 2	22 29	15 0	0 0	0.00028

Note: Numbers in bold are initial student responses ("pre" positions); the numbers underneath are final student responses ("post" positions). ^aThis aggregated value obscures the opposing effects in the two sections: in the presenting section "agree" responses decreased from 4 to 1; "disagree" responses increased from 17 to 25; and "undecided" responses declined from 8 to 4.

Influence of Advocacy on Student Responses

Of the propositions that were offered all six years, proposition 6 concerning nuclear power generation was presented orally three times. In 1997 and 2002, the peer presentations opposed the proposition while in 1999 the presenting group supported the proposition. In all three cases, the final class response was in the direction advocated and was highly significant ($p \leq 0.01$) in 1999 and 2002, but on opposite sides of the issue (Table 3). There was no significant change in student responses for this proposition in the other three years, although there seemed to be a small carryover effect of the 1999 presentation in 2000 and 2001 in terms of the increase in the agree response. Perhaps this was due to the ~25% of the students who reviewed the 1999 group's Web site in subsequent years, although such effects are not apparent for other propositions.

Impact of Advocacy on Undecided Peers

Achieving significant changes in student responses is more difficult when the presenting group advocates a position already strongly held by their peers. There is not much room for change unless there are a substantial number of

undecided students, as there were in 2002 with the proposition on nuclear power generation (Table 3). In other cases available in the Supplementary Materials^W and Table 4, excellent seminars had very little impact because there were few students who were undecided initially.

Student Awareness as a Factor in Changing Responses

Even when a presenting group advocates a position not held by many students, if the positions are well established due to widespread personal awareness as indicated by few undecided students, significant changes in position rarely occur. Such issues include use of anabolic steroids, deterrents to careers in science education, conflict between science and religion, approval of the "morning after" pill, and limiting consumption of gasoline, cigarettes, caffeine, or meat. On the specific issue of whether low salaries deter chemistry and biochemistry majors from becoming high school science teachers, students mostly agreed or disagreed with few undecided. The proposition was presented in two of the five years it was offered and both times it generated lively, even heated, discussion in the question and answer session. However, there were no significant changes in the pre versus post responses.

Table 4. Effect of the Percentage of Initially Undecided Students on the Impact of Peer Presentations

Proposition Statement	Initially Undecided, %	Finally Undecided, %	p-Values
Five propositions with the highest percentage of initially undecided students			
1. Dioxin is not as toxic as the press makes it out to be.	83	11.1	3.50×10^{-12}
2. The use of antibiotics in animal food represents a long-term health hazard to humans by promoting antibiotic resistance in pathogens.	77.8	17.5	1.7×10^{-2a}
3. Drinking water should be treated with hydrogen peroxide rather than chlorine.	70.2	37.8	1.90×10^{-2}
4. Estrogen replacement therapy is a safe and effective way to treat the effects of menopause.	60.5	16.1	3.80×10^{-6}
5. Anti-knock compounds in gasoline that have replaced tetraethyl lead are likely to produce environmental problems also.	60	28.5	2.30×10^{-2}
Five propositions with the lowest percentage of initially undecided students			
1. The negative effects of caffeine are sufficient enough that individuals should limit their consumption of it.	5.9	2	2.90×10^2
2. Raising gasoline prices in the U.S. would provide the incentive for engineering automobiles with improved fuel efficiency.	7.1	14	0.557
3. Chemical and biological warfare should be considered as viable components of a national security program.	8.9	12.8	0.550
4. Knowledge of the genetic determinants of human behavior should be used to screen infants to identify and monitor people who may become criminals as adults.	10.3	7.1	0.332
5. Low salary is the major deterrent to chemistry and biochemistry majors who might otherwise consider careers as high school science teachers.	10.5	0	0.221

^aThis represents the summed analysis of two separate presentations, each of which was significant at the $p = 0.05$ level.

At the other extreme, when few students have a position and a large number are undecided, student presentations usually generate a significant difference in the pre versus post responses. The change with the highest significance observed in the six years of this study occurred in this situation (Table 4). The proposition was “dioxin is not as toxic as the press makes it out to be”. Of the initial responses, 1 agreed, 6 disagreed, and 39 were undecided out of 47. In the final responses 33 agreed, 6 disagreed, and 5 were undecided out of 45 responses with a probability of 3.5×10^{-12} that the pre-post difference was due to chance. The following year this proposition was offered with the same wording but not selected for presentation. There was still a very high undecided portion of the class and there was no significant difference in the pre-post responses. Because students had reviewed the Web site from the previous year when there was a large change in student attitude, this result highlights the relatively weak influence that peer constructed Web sites have relative to oral presentations on changing student positions.

These examples and others are illustrated in Table 4 where the impact of oral presentations for the five propositions with a highest percentage of initially undecided students are compared to the five propositions with the lowest percentages. Of the five presentations on topics with more than 60% of the students initially undecided, all resulted in a significant difference in the pre versus post course responses. Of the five presentations to audiences with the fewest undecided members, only one achieved statistical significance at the $p = 0.05$ level.

Discussion

Effectiveness of Student Seminars on Changing Peer Positions

While we are interested and intrigued by the attitudes of our seniors in chemistry and biochemistry, this study does not deal directly with the attitudes students have. Rather, we are concerned with whether and how student responses to a proposition change statistically in response to a specific intervention—a seminar on the proposition topic by peers. We show that attendance at a seminar by peers on a topic is strongly associated with changes in pre-post course responses to a proposition on that topic, particularly if the initial responses to the proposition include a high proportion of undecided students. Our observation that student responses are remarkably stable in the absence of intervention makes the effects of peer presentations all the more apparent.

Although classmates reviewed Web sites created by each presenting peer group, we conclude that pre-post course changes occurred predominantly because of the oral presentations rather than the Web sites, for three main reasons. First, each class of students reviewed Web sites from previous classes with no significant effect on subsequent responses to the associated propositions.^W Second, although Web sites were reviewed equally between the two sections in the same year, attendance at the seminars was not equivalent. The statistically significant changes usually occurred in the section in which the oral presentation was made and rarely in the other section. Last, the rank order in Web site quality as determined

by student evaluations was poorly correlated with the observed changes in students' pre-post course responses to the same propositions. This may be related to the instructors' impression that Web site construction and peer evaluations of Web sites often valued visual impact and technical skill more than the quality of the argument for or against a proposition.

In the seminar presentations, as well, acceptance of particular positions seemed uncritical to the instructors and was occasionally associated with emotional, rather than logical, arguments. For example, personal testimony (“ritalin works for me”, or “my mother died of cancer”) sometimes substituted for substantive available information or did not address the issue. Other times substantive information provided impact without rigorous connection to the proposition, thereby creating an argument by assertion, rather than by reason.

Sources of Student Knowledge on Societal Issues

The pre-post course stability in student responses to propositions for which no intervention occurred was a robust result. One might expect that students would encounter some of these topics in the newspapers, on television, or in other courses. Furthermore, some of the presented topics might have crossover impact on other related topics. To the extent that students encountered these topics in other contexts, this had no significant effect on attitudes. From an educational perspective, it is interesting to know how students acquire and modify the attitudes they have.

Others have studied the factors that influence public opinion and have concluded that television news anchors, interviewed experts, and popular presidents have significant impact, which translates to several percentage points in national surveys (7). With the average viewer age over 50 for national television news (8), it is evident that college students are not a major part of that audience. If students do not learn about societal issues related to chemistry in science courses and they don't watch the daily news, do they learn about these issues by reading on their own? Most probably do not.

In a required second-year course for biochemistry majors, about half of the students who enroll in the chemistry senior seminar 18 months later were asked, “What newspaper, magazines, or journals do you subscribe to or read regularly?” Of the cohort involved in this study (1995–2000), fewer than 20% listed *Scientific American*, *National Geographic*, *Chemical and Engineering News*, *Discover*, or other publication with a science slant. Fully 29% of these students reported not subscribing to or reading any newspaper, magazine, or journal.

Implications

Beyond the issues related to the influence of peer presentations on changing student attitudes, implications of our study concern the education of future chemists who will be expected to apply their scientific expertise to societal issues either professionally or as citizens. The societal issues identified by the propositions used in this study are typically controversial and become politicized in public debates that neglect the underlying chemical science. It is important that chemistry students develop both increased awareness of these issues and the background to constructively engage in the debates.

While it is common for faculty to avoid societal issues in teaching chemistry because “it is not chemistry”, these are the very topics that can make chemistry relevant to majors and nonmajors alike. Based on our experience and the results reported here, chemistry and biochemistry graduates have made few connections between what they have learned and how it relates to societal issues. We and others (9) have used a senior seminar as a capstone course to introduce societal issues into the chemistry curriculum. In the process, we want students to develop critical thinking skills, practice communication skills, and gain confidence in their ability to think through public policy issues related to science. If students are to develop greater awareness of the role of chemistry in society by the time they graduate, it appears they need to confront these issues earlier in their studies, perhaps in the context of chemistry courses or together with peers in social sciences and humanities who should also be aware of these issues.

Acknowledgments

We thank Joel Best, Willett Kempton, Jean White, and Laura White for their helpful comments on drafts of this manuscript.

^uSupplemental Materials

A synopsis of the 78 propositions used in the course and statistical analyses of the students' pre-post responses to every

proposition by section and year are available in this issue of *JCE Online*.

Literature Cited

1. American Chemical Society Committee on Professional Training, Undergraduate Professional Education in Chemistry. *Guidelines and Evaluation Procedures*; ACS: Washington, DC, 2003.
2. Voet, J. G.; Bell, E.; Boyer, R.; Boyle, J.; O'Leary, M.; Zimmermann, J. K. *Biochem. Mol. Biol. Educ.* **2003**, *31*, 161–162.
3. *Journal of Chemical Education* Buyers Guide, February 2004; <http://www.jce.divched.org/JCEWWW/Features/BG.html>.
4. Stanitski, C.; Eubanks, L. P.; Middlecamp, C.; Pienta, N. J.; Stratton, W. *Chemistry in Context: Applying Chemistry to Society*; McGraw-Hill Companies: New York, 2003.
5. White, H. B., III; Panar, M.; Johnston, M. V. *J. Chem. Educ.* **2000**, *77*, 1590–1593.
6. Cox, C. P. *A Handbook of Introductory Statistical Methods*; John Wiley and Sons: New York, 1987; pp 62–85.
7. Page, B. I.; Shapiro, R. Y.; Dempsey G. R. *Am. Pol. Sci. Rev.* **1987**, *81*, 23–43.
8. Public's News Habits Little Changed by September 11. The Pew Research Center: Washington, DC, 2002; <http://peoplepress.org/reports/display.php3?PageID=613> (accessed July 2005).
9. Caspers, M. L.; Roberts-Kirchoff, E. S. *Biochem. Mol. Biol. Educ.* **2003**, *31*, 298–302.