A Directed Framework for Integrating Ethics into Chemistry Curricula and Programs Using Real and Fictional Case Studies

Ellen R. Fisher* and Nancy E. Levinger

Department of Chemistry, Colorado State University, Fort Collins, CO 80523-1872; *erfisher@lamar.colostate.edu

Science is based on trust. Without honesty, scientists would never share their ideas or results for fear that other members of the scientific community would copy or steal their work. Science is thus built on a policy of conduct above reproach. At the same time, science is a social enterprise, which means that people and their personal agendas are involved. Thus follow the usual "deadly sins" of all social enterprises: power, money, greed, sloth, revenge, prestige, and control. Recent high profile cases of misconduct and fraud have brought increased attention and awareness of the public to the ethical practices of researchers in this country *(1, 2).* As several authors have recently suggested *(1, 3–7),* it is important to teach young scientists explicitly about appropriate ethical behavior. This does not, however, always fit well into any single course required by the American Chemical Society (ACS) to complete the ACS-certified degree in chemistry *(8).* So how do chemistry students learn scientific ethics and responsible conduct of research?

In a world of ever-increasing complexity, teaching students how to evaluate appropriate ethical behavior is critically important. Indeed, the National Science Foundation's Research Experiences for Undergraduates (NSF-REU) program *(9),* has heightened their emphasis on teaching ethics by urging principal investigators to include an ethics component in their programs. In addition, many students entering college appear not to understand what constitutes unethical behavior. To address these issues, we have developed a flexible, effective method to teach students with varying degrees of expertise about scientific ethics at a wide range of levels and in several different venues from high school science classes to undergraduate courses to REU programs to conference workshops for graduate and postdoctoral students. The approach uses directed case studies as a framework for a discussion of various topics in scientific ethics.

An Active Learning Approach for Teaching Ethics

The use of case studies to teach scientific ethics has been discussed in several articles in this *Journal (1, 10)* as well as in books devoted to the topic *(4, 11–14).* Numerous Web sites provide information on the topic of scientific ethics, including case studies *(15–18).* Here, we present an active learning approach to teaching scientific ethics within the context of chemistry classes and research programs using case studies with real and fictional ethical dilemmas in a directed framework.

This approach differs from others presented in the literature in several ways. First, the activities are participatory; rather than providing a list of "do's and don't's", students learn through actively participating in group discussions of case studies and reasoning through possible actions and outcomes for each case. Although many possible actions for any given scenario exist, we discuss the possibility of significant negative consequences for particular actions that deviate from the accepted practices in science. This approach provides the opportunity to discuss "right" and "wrong" answers without dictating a specific action.

Second, we present a range of case studies that vary in complexity from simple cases for younger, less-experienced students, to complicated, multipart scenarios for groups with more experience. Although the activities are virtually identical in each venue, the key is to hone the case studies for relevance to the particular group rather than to assume a "one-size-fits-all" model of ethics instruction. We also attempt to develop each case study by adding additional tidbits as the discussion develops, in an effort to fully engage all of the students.

Finally, the scenarios presented have all been used with real students in a range of environments. The program has also been used by others—for example, by the director of the Integrated Science Program at Northwestern University—demonstrating its transferability. Although primarily anecdotal in nature, feedback from summer undergraduate research groups, graduate students (via a course on responsible conduct in research taught Spring 2007 at Colorado State University), and faculty observers has been excellent. Through the context of our newly funded REU program, we anticipate developing specific assessment tools and metrics for the ethics component.

Discussing Ethics in Science with Students

Our ethics exercises always begin with presentation of some background and ground rules. Here we give some general definition of ethics, essentially "a set of moral values and principles", and then discuss more specifically "professional ethics", which apply the general rules of ethics to the given profession. Thus, scientific ethics refers to standards of conduct for scientists in their professional endeavors. This requires adherence to principles and practices of valid scientific experimentation, education and mentoring, peer review, and communication of results to the public. Note that the facilitators will often distinguish for students the difference between "morals" and "ethics", the former generally refers to aspects of human action whereas the latter refers to professional behavior, although they are often used interchangeably *(11).* As we usually present this discussion in one session, either one class period (1–2 hours) or a workshop session (2–3 hours), we do not often go into extended discussions of moral reasoning and ethical theory. Rather, we focus on practical ethics and decision making skills, leaving a more formal presentation of ethics to multisession courses or meetings.

From the definitions given above, the group is charged with discussing who generally decides what constitutes ethical behavior for a particular professional group and where such guidelines might be found (e.g., ACS's *The Chemist's Code of Conduct, The American Institute of Chemical Engineers' Code,* refs *19* and *20*). This is followed by a short description of the definition of scientific misconduct. In general, three activities, falsification, fabrication, and plagiarism, jointly comprise the definition of scientific misconduct *(21).* Falsification involves a misrepresentation of results; fabrication refers to reporting on work never performed. Plagiarism is usually considered to be

taking the writings or ideas of another and representing them as one's own. As many of these ideas are somewhat abstract, especially to the uninitiated, we have developed highly interactive and instructive ethics exercises based on real and fictional case studies to help students recognize and understand the code of responsible conduct expected of scientists.

Rules of Engagement

Before beginning the exercises, students also learn ground rules for the ensuing discussion. There are two primary rules for the discussion. First, often no right or wrong answers to the ethical dilemmas are presented in the case studies. This rule is imperative for the discussion to be inclusive of all students' views. Giving them a list of "do's" and "don't's" or suggesting that you will be "laying down the law" in these sessions can alienate some students, precluding them from participating in and learning from the discussion *(11)*. Usually, from the ensuing discussion of the situation, the group will agree on the "best" way to handle the particular situation presented in a given scenario. Students are also reminded that several ambiguities exist within the scenarios, including important data or information that could change viewpoints. Thus, the end result may be a list of additional factors or questions that need to be answered to respond appropriately to the situation. As noted above, this is not saying that there are no "accepted rules" about appropriate behavior in many given situations. Our goal for these exercises is to help individuals develop information-seeking routes to understand the underlying ethical dilemmas. The primary purpose of this rule is to suggest to students that although there may be some inappropriate behaviors, "gray areas" also exist and sometimes the appropriate course of action is to seek additional information or guidance from appropriate sources.

The second discussion rule raises the point that individual decisions or solutions presented during the discussion must be respected even if some members disagree. Students are guided to learn that people make decisions based on a range of personal attributes, including demographics such as age, race, ethnicity, religion, or culture, as well as education and experience. From this discussion, we also offer a short introduction to moral reasoning, often using the case of Heinz and the druggist (see Table 1), as it offers a seemingly simple scenario that can be readily grasped by students *(22)*. After this prologue, case studies are presented, followed by specific questions and discussion.

A critical part of these exercises is the participation of *all* the group members. Generally, a few more vocal members will tend to dominate discussion, sometimes intimidating less confi-

Table 1. Case Studies for Discussion of Various Ethical Issues

Issue	Student Level	Context	Reference*
Plagiarism	High school and undergraduate	Lab report	S1
	Graduate	Copying text for a thesis or preliminary exam	*21*, S2
	Senior graduate and postdoctoral	Copying an idea in a grant	*4*
Credit and blame	Undergraduate	Sharing lab data	Case #1
	Graduate and postdoctoral	Authorship	*21*
Conflicts of interest	Undergraduate	Supporting unethical behavior, such as facilitating others' cheating	S3
	Graduate and postdoctoral	Romantic relationship with a superior	*22*
		Reviewing and consulting arrangements	*21, 4*
Data manipulation	High school and undergraduate	Cooking, forging, trimming data (e.g. Abel and Baker)	*23*
	Graduate and postdoctoral	Data trimming without appropriate statistical testing	*21*
Forging teamwork	Undergraduate	"Dry labbing"	S4
	Graduate and postdoctoral	Publicized forgery (e.g., Bell Labs organic LEDs or heavy elements)	S5
Resource allocation and sharing	Undergraduate	Hoarding equipment to prevent others from succeeding	S6
	Graduate and postdoctoral	Unequal distribution of resources	S7
		Sharing of research materials	S8
Safety and risk	Undergraduate	Tolerating unsafe behavior in laboratory settings	S9
	Graduate and postdoctoral	Assessing who makes decisions for safety: drug testing in humans	*11, 14*
Stealing	Undergraduate	Taking small lab equipment	S10
	Graduate	Deleting others' data	S11
	Postdoctoral	Faculty member using student ideas in a grant application	S12
Job searching	Undergraduate, graduate, postdoctoral	Conducting an ethical job search	Case #2
Social responsibility of scientists	Undergraduate	Pharmaceutical industry: Heinz and the druggist	*22*
	Graduate and postdoctoral	Environmental effects: The Galston case (agent orange)	S13
		Biomedical research: The Tuskegee syphilis trials	S14
Intellectual property and record keeping	Undergraduate, graduate, postdoctoral	The invention of the laser	*27*
		The Genentech case	S15
		Cantor's dilemma	S16

*See cited literature references or online supplement. Case studies and additional comments in the online supplement are numbered S1, S2, etc.

dent members. This situation can largely be overcome by having the leader solicit the input from quieter individuals, seeking their opinions. Once a person has voiced an opinion, they tend to be drawn into the discussion and will participate again. We find it is rare that any individual will not have an opinion or be willing to voice it. We have also found it is useful to point out to participants that the opinions expressed by the facilitators may not be their own personal opinion, rather they may be alternate views expressed to spark discussion and help students see other possible sides of the story.

Selection and Presentation of Case Studies

In our experience presenting numerous workshops and course units on scientific ethics over the past decade or so, we have found that the selection of appropriate case studies is critical to successfully engaging students and addressing the specific needs of the group. One observation we have made is that students respond particularly well to cases identified as "real", either those reported in the news or actual events that the facilitators experienced. This is especially true when the group can discuss what they would have done and then what the actions and consequences were for the real stakeholders in the scenario. Some cases, however, are simply not appropriate for certain audiences and thus we tailor selections to address the most relevant issues for any particular audience. We provide examples below.

The first case study presented for any audience should pose a relatively simple and obvious ethical question, yet one for which students may form differing opinions. For high school students or college freshmen, Case 1 works well *(17)*. This scenario contains characters and a situation familiar to any student who has taken a laboratory course.

Case 1 for High School or First-Year College Students

> Pete, Brooke, and Lisa are lab partners in their chemistry class. Yesterday, Lisa was absent. This required Pete and Brooke to work very diligently to complete the experiment during the lab period so they could hand in the report in class today. Today Lisa has returned to school after being ill. She meets her lab partners on the way into school in the morning and asks them for the data from yesterday's experiment so she can write it up during study period and hand it in.

The question posed to students following presentation of this scenario is, "Should Pete and Brooke let Lisa copy their data?". Invariably, students choose sides on this issue and it is relatively easy to spark debate. Some students feel that Pete and Brooke should not share the data, while others suggest that it is the interpretation of the data that will count in the course, not the actual data. Frequently students contend that it does not matter since "it is just a laboratory course". If students all choose the same interpretation, the instructor or leader can introduce additional information. For example, if all the students think that the data should be shared, then the facilitator can place doubt in their minds by suggesting that Lisa may not have been ill, instead she was skipping school. The point of the exercise is to get students thinking about what they consider appropriate behavior and why.

When students express the feeling that the scenario presents a trivial issue of no ethical import, a perfect segue is provided for the leader to ask the group to identify who will be affected by the situation; that is, who the stakeholders are. This clearly brings the group back to the concept of moral reasoning *(22)*. In addition, although students may consider this case to be trivial, it also allows the leader to explore the students' views and understanding of when the case is no longer trivial. That is, if allowing a classmate to copy data is acceptable in a high school or first-year level course, when does this practice lose its trivial nature and become a serious offense that may fall under the category of fabrication or falsification of data? Sharing data is, of course, a critical component to the advancement of science and various funding agencies have explicit rules regarding such matters. In other scenarios (see case study S8 in the online supplement), we address issues surrounding sharing data, reagents, and knowledge and the antithesis—precluding others from knowing results to prevent them from being able to compete.

We have also had success using the case of Abel and Baker presented by Treichel *(23)* as a case study. Here, students are asked to decide which of three scenarios is *least* defensible: Abel and Baker manipulating data by trimming (eliminating data), forging (fabricating data), or cooking (adjusting the data). After listening to and reading the three scenarios, students nearly always decide that forging the data—that is, making up a data point—is worst, although, upon reflection, they recognize that all are wrong. These particular scenarios are useful as the facilitator can compel students to rank behavior. They must then defend their position and often they lobby other students to change their votes. More importantly, this allows discussion of definitions of misconduct and solidifies the abstract definitions given at the beginning of the discussion.

Overall, the key to choosing scenarios for use with younger scientists is to have characters and situations that the students can directly identify with. The characters can have exaggerated behavior, yet must respond to the situation in at least a somewhat realistic manner. These cases can serve as an introduction to moral problem-solving (reasoning) and allow students to learn conventions or rules for appropriate conduct. Learning these conventions, rules, and techniques allows students to tackle more complicated scenarios requiring more experience even when they are relatively naïve. Some examples of additional scenarios are included in Table I and the online supplement.

A Case Study in Four Parts for Upper-Level Undergraduate or Graduate Students

As the experience level and maturity of the students increase, the complexity of the cases used can and should change. With more advanced students, we attempt to develop moral reasoning and create more opportunities for comparison of unethical practices. Specifically, our case studies at this level are more designed to engage students in discussions about "line drawing", and thereby consider the question, "Are there differing levels of misconduct?" This has been described by others as "high crimes" and "misdemeanors" *(7)*. Students have often remarked that this particular aspect of our ethics sessions was the most thought-provoking, forcing them to examine their own behaviors and decision-making processes.

We have developed more complex case studies that serialize the issues. In other words, rather than discussing an isolated incident, students are forced to choose a particular path for characters on which future actions will depend; then they find out what choices the characters actually made. This allows for the visualization of consequences of their choices and adds a greater sense of realism to the scenarios.

The case studies we have developed for this exercise have arisen largely from real experiences of unethical behavior and have been adapted to appeal to our audiences. Our "real" case studies are always fictionalized to protect the identity of individuals involved in the actual situations. Case 2, The Job Search, offers an example of a serialized case study that presents a variety of ethical issues associated with application for and acceptance of employment. This scenario, the first part of which was loosely based on a case in Seebauer and Barry *(11),* can easily be generalized to application and acceptance into *any* program or position a person might consider, including but not limited to a summer research program, industrial or academic jobs, fellowships, and so forth. Subsequent parts grew out of real-life situations we and our colleagues have experienced from both sides of the job search process.

The Job Search: Part I of Case 2

> Andy is a senior environmental engineering major at Western University, where he is a good student with a high grade point average. Unfortunately, the job market has not been that great and few companies have been interviewing, much less hiring. Last week, he had an on-campus interview with Tripos Chemical Company and now they have offered him a plant trip. After the interview, Andy reads an article in *C&E News.* The article said that Tripos has a long record of pollution violations, with lots of fines and all sorts of legal troubles over it. If they lose enough cases, they could go bankrupt. In addition, the article stated that the company sells chemicals overseas that are banned in the U.S. because of toxicity concerns. Now Andy is not sure whether to go on the plant trip and he is really not sure he wants to work for a company that "makes stuff that kills people". Maria, one of Andy's friends, suggests that perhaps the company is trying to turn things around by hiring environmental engineers such as Andy. Andy is not convinced and is not sure he wants to "lead the charge" against all those problems.

Following presentation of Part I, a discussion of the ethical dilemma posed (i.e., personal moral beliefs vs having a job) ensues, and the possible choices for the main character, Andy, in this situation are presented. In general, students believe that Andy should go on the plant trip and find out about the company first-hand. In Part II of Case 2, students discover what Andy does as well as the ensuing ethical dilemma that results from his receiving a job offer. After presentation of Part II, students are again asked to identify and discuss the ethical dilemma and possible responses for Andy. We also discuss possible options that Andy might have, including what he might have done when he received the initial offer from Tripos. This allows for the facilitator to introduce to students the concept of negotiating, another often-neglected aspect of students' education and one that has significant ramifications in the area of ethical behavior.

The Job Search: Part II of Case 2

> Andy decides to go ahead and take the plant trip, thinking that at least that way he can check out the company for himself. Although Tripos is not as bad as he feared, he is still not comfortable with their environmental record. After the plant trip, he receives a job offer from Tripos for a lot of money, and it is the only job offer he has. Tripos gives him two weeks to make a decision about the position.
>
> Meanwhile, Andy also receives an offer for a plant trip to XT Chemical Company: Andy's ideal job at the ideal company. The trip is scheduled for the end of the two-week period Tripos has given him. Andy visits XT, but doesn't feel the interview went well, especially his seminar. Everyone at XT asked him lots of questions and he was not sure of all of the answers. No other companies have contacted Andy. As the Tripos deadline approaches, Andy decides that XT will not offer him a position, so he takes the job at Tripos. Two days after formally accepting the Tripos offer, Andy gets a verbal offer from XT. Now, Andy wants to renege on Tripos and take the job with XT.

Parts IIIa, IIIb, and IV of Case 2 present additional aspects of job hunting. Various discussion topics that this serial case study has stimulated include (a) "formal acceptance" of an offer; (b) the ethics associated with "giving your word" to someone; (c) possible recourse for both companies and individuals for failure to fulfill "contracts" of employment; (d) ethical obligations to other job applicants (Case 2, Part IV); and (e) debates on personal choices and social obligations in a "post-Enron" world *(24, 25).* We would also note that this particular scenario works with audiences at *all* levels, from undergraduate students to graduate students to postdoctoral researchers and assistant professors, as all of these groups either have been or will soon be involved in the process of making career decisions.

The Job Search: Part III of Case 2

> (a) Andy decides to renege on Tripos, but is not sure how to let them know that he has changed his mind. So he does nothing and pretty soon, his intended start date has come and gone. Several times, representatives from Tripos' HR department have called and left messages on Andy's answering machine. He has taken to screening all of his calls. Pretty soon, the calls stop.
>
> (b) In the mean time, Andy accepts the offer from XT Chemical Company, and sets a start date. The week before his scheduled start date, Joe, his contact at XT, says that unfortunately, they have just heard that they are going to be laying off 500 employees and the company has thus instigated a hiring freeze. As Andy had not yet started work, they were rescinding the job offer. Joe says he's really sorry and that maybe in six months to a year, they'll be able to do something, but no promises.

The Job Search: Part IV of Case 2

> Andy's friend Maria is also searching for a job. She's a chemist and the job market has remained stable. Because Maria is bilingual and has two years of laboratory experience, she is a "hot" commodity. She has had numerous on-campus interviews and has scheduled nine plant trips. After the first three trips, she knows that if Tetra-Gen offers her a job, she will take it. It's in a great location and the job was made for her. Plus she'll get to travel, which she loves to do. After Maria returns from her fifth plant trip, she has a message from Tetra-Gen—they want to hire her and they're willing to wait for her to finish the school year and even take some time off before starting work. Plus they're giving her a "signing bonus" of $3000. Maria thanks the Tetra-Gen representative and tells her she will have to think about it.

Andy can't believe it:

"Maria, don't you want this job? If you mess around with them you may be out of job just like I am. You should call them immediately and tell them you'll accept their offer."

Maria counters with,

"I know I'm going to take the Tetra-Gen offer, but I still want to go on these other plant trips. You know how I love to travel, plus they always take you to great restaurants and I'll really get to rack up the frequent flier miles."

Recently, we have explored the use of video clips to provide a dramatic version of effective case studies and to discuss more complex aspects of ethical behavior that may be more difficult to depict effectively in a simplified scenario. One particularly effective video clip we have used with summer undergraduate students and with new graduate students comes from the movie *And the Band Played On*. This movie focuses on the politics and policy decisions made during the search for the AIDS virus. Others have used the entire film or large fractions of it as the basis for an in-depth discussion of all of the issues associated with this subject *(26)*. We find that using only two chapters from the movie is sufficient to spur discussion of the issues associated with sharing of research materials. The selected chapters (see the online supplement) focus on the initial discovery of the AIDS virus and the labs that were competing in the search: an American group at the National Institutes of Health (NIH), a French group at the Institut Pasteur, and a third group, also American, at the Centers for Disease Control (CDC) in Atlanta. The two chapters depict how different labs responded to requests for research materials and allude to the consequences (both positive and negative) of different choices the "characters" make. (More details are provided in the online supplement.) This allows for a deeper discussion of public policies and obligations of researchers using federal funds for their work, as well as on social responsibilities of scientists. Table 1 and the online supplement provide more details on the use of these scenes. Based on the response of two different groups of students (i.e., undergraduates and graduate students), use of such video clips with all levels of students can provide a very effective means of presenting ethical case studies and sparking lively discussion.

Reception to Using Case Studies on Scientific Ethics

We have used these case studies in a wide range of different environments with much success. Most frequently, we have presented this as a workshop for summer research students in a NSF-REU program or in one, two-hour class period of the capstone senior seminar course in chemistry at Colorado State University. In both these venues the reviews from students are excellent; 90% of the students in these groups (results from three groups of summer students, $n = 27$, and three senior seminar classes, $n = 36$) rated the activity as "fantastic" or "good" (on a scale of fantastic, good, ok, dull, horrible). More tailored versions of the program have been taken to meetings and workshops, for example, the Academic Careers in Chemistry at the Eastern Analytical Symposium. We have even presented a version (and developed a scenario specifically for this group that we now have incorporated into other presentations) at a high school in Denver, CO. The program is also easily transferable. After observing the presentation to students in the Integrated Science Program at Northwestern University, the director has continued to use our material to teach ethics to the students there. What makes this program effective is that the case studies work easily for groups with differing backgrounds and experience.

Many of the case studies we have developed and used work well with groups of participants from those with little professional preparation to more experienced graduate and postdoctoral students. Clearly some topics covered are universal, such as plagiarism, cheating, data manipulation, credit and blame, forgery, conflicts of interest, stealing, resource allocation, safety and risk. But the effectiveness of the discussion depends on the presentation. For example, when discussing plagiarism with high school students, copying a lab report from a classmate is an appropriate case study, whereas for a graduate student, a more appropriate discussion would involve copying text from a paper or a book into a preliminary oral exam report. For senior graduate or postdoctoral students, plagiarism might well be discussed in the context of using another's idea in a grant application. We increase the complexity of the discussion by introducing different follow-up questions depending on the group. For example, Case 2 can be equally effective for young students applying for summer research positions or internships as it is for postdoctoral and graduate students who relate to this exercise when applying for permanent employment. Facilitators can add perspective through anecdotal stories they have personally experienced. Table 1 provides a list of topics, identifying the ethical issue and a reference (either to the literature or the online supplement) to an appropriate case study.

Examples of Less-Effective Ethics Case Studies

Interestingly, we have found that some of the scenarios we have developed ourselves or attempted to use from other sources do not work for certain groups. Obviously, some simple scenarios that are highly effective for younger students seem trivial for more experienced groups. Likewise, when using a scenario probing the ethical dilemma of a supervisor having romantic involvement with their subordinate, such as the Bob Bailey case presented by Bebeau et al. *(22),* we find that undergraduate students of all levels have difficulty forming opinions and making ethical choices about the scenario. This is especially true when the students are asked to assume the role of a superior, such as a department chair or university president. We believe this occurs primarily because such roles are too far outside the realm of the students' experiences; thus, they do not have a sufficient framework from which to formulate a reasonable solution to the dilemma. Moreover, they find it difficult to identify with the individuals involved or even to identify stakeholders (such as the university), so they are unable to effectively evaluate the possible behaviors of the characters.

Especially with figures in supervisory roles, students have little understanding of the inherent obligations to institutions that such positions bring. Thus, they tend to focus on what is best for the individuals involved with little value placed on what the institutional needs may be. For example, when asked whether the department chair should act on information about a romantic relationship between a graduate student and an advisor, undergraduate students often miss the larger issues. Typical responses from students are: "It's none of the chair's business"; "I don't think the Department should know"; or "I don't see what the problem is". These scenarios do, however, work reasonably well with more advanced students or groups comprising pri-

marily postdoctoral associates or junior faculty. Although these results were not directly measured via course surveys or other assessment tools, these statements are based on comparing the amount of discussion (i.e., time, difficulty in getting students to respond) on this scenario versus discussion on other scenarios used with the same group of students. Because we find several of our scenarios have varying degrees of effectiveness (as assessed by the facilitators) for different groups, we provide examples in Table 1 of scenarios and specific groups to which the programs are best directed.

Conclusion

As situations requiring experience with scientific ethics become increasingly common, it is critical that this become a regular part of student instruction. Discussions of case studies are an effective and enjoyable way to teach scientists with different levels of preparation. Here, we have presented an approach to teaching scientific ethics to groups of students that can be tailored to the group's experience and maturity. This program captivates students' interest, engaging them in discussions that facilitate learning. We show how the program can be honed to the specific group and increased in complexity depending on the direction a particular discussion takes. Overall, this approach represents a tested, flexible, highly transferable and easy to implement program to address instruction in scientific ethics for a variety of student levels, from high school through advanced graduate and postdoctoral.

Acknowledgments

We thank colleagues at Colorado State University who have provided some of the material we have adapted to our invented case studies, especially Dawn Rickey and Lisa Dysleski. In addition, we thank the students who have participated in presentations through a NSF-REU program (NSF-0244181 and NSF-0649263), the capstone senior seminar course (C493), and the Academic Careers in Chemistry Workshop at the Eastern Analytical Symposium (NSF-0132781).

Literature Cited

1. Niece, B. K. *J. Chem. Educ.* **2005,** *82,* 1521–1522.
2. Dalton, R. *Nature* **2002,** *420,* 728–729.
3. Coppola, B. P. *J. Chem. Educ.* **2000,** *77,* 1506–1511.
4. Kovac, J. *The Ethical Chemist,* 1st ed.; Pearson Education, Inc.: Upper Saddle River, NJ, 2004.
5. Mabrouk, P. A. *J. Chem. Educ.* **2001,** *78,* 1628–1631.
6. Zigmond, M. J. *Sci. Eng. Ethics* **2003,** *9,* 191–200.
7. Zigmond, M. J.; Fischer, B. A. *Sci. Eng. Ethics* **2002,** *8,* 1–7.
8. ACS Committee on Professional Training, Undergraduate Professional Education in Chemistry Guidelines. *http://portal.acs.org:80/portal/fileFetch/C/CTP_003934/pdf/CTP_003934.pdf* (accessed Mar 2008).
9. NSF-REU Program Home Page. *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&from=fund* (accessed Mar 2008).
10. Shachter, A. M. *J. Chem. Educ.* **2003,** *80,* 507–512.
11. Seebauer, E. G.; Barry, R. L. *Fundamentals of Ethics for Scientists and Engineers,* 1st ed.; Oxford University Press: New York, 2001.
12. *Research Ethics: Cases and Materials;* Penslar, R. L., Ed.; Indiana University Press: Bloomington, IN, 1995.
13. Resnik, D. B. *The Ethics of Science: An Introduction;* Routledge: New York, 1998.
14. Macrina, F. L. *Scientific Integrity;* ASM Press: Portland, OR, 2005.
15. Online Ethics Home Page, Online Ethics Center for Engineering, National Academy of Engineering. *http://onlineethics.org* (accessed Mar 2008).
16. Teaching Ethics for Research, Scholarship, and Practice. *http://www.research.umn.edu/ethics/curriculum/* (accessed Mar 2008).
17. Adapted from Lesson 2, Student and Teacher Behaviors in Science. *http://onlineethics.org/CMS/edu/precol/scienceclass/lessonplans/lesson2.aspx* (accessed Mar 2008).
18. Zigmond, M. J.; Fischer, B. Survival Skills and Ethics Program. *http://www.survival.pitt.edu/* (accessed Mar 2008).
19. Bruton, S. V. *J. Chem. Educ.* **2003,** *80,* 503–506.
20. American Institute of Chemical Engineers Code of Ethics. *http://www.aiche.org/About/Code.aspx* (accessed Mar 2008).
21. Committee on Science, Engineering, and Public Policy. *On Being a Scientist: Responsible Conduct in Research;* National Academy Press: Washington, DC, 1995.
22. Bebeau, M. J.; Pimple, K. D.; Muskavitch, M. T.; Borden, S. L.; Smith, D. H. *Moral Reasoning in Scientific Research: Cases for Teaching and Assessment;* Indiana University: Bloomington, IN, 1995.
23. Treichel, P. M. *J. Chem. Educ.* **1999,** *76,* 1327–1329.
24. Conroy, S. J.; Emerson, T. L. N. *Social Sci. Quarterly* **2006,** *87,* 395–410.
25. Romero, S.; Hard Times Haunt Enron's Ex-Workers. *New York Times,* January 25, 2006, C1.
26. Zigmund, M. J.; Fischer, B. Ethics at the Movies. Presentation at the Teaching Survival Skills and Ethics Conference, Snowmass, CO, June 11–16, 2006.
27. Kanare, H. M. *Writing the Laboratory Notebook;* American Chemical Society: Washington, DC, 1985.
28. Weiss, P. *Science News* **2002,** *162,* 37–38.
29. Mooney, P. *Chronicle of Higher Education* **2006,** *52,* A49.
30. Bhattacharjee, Y. *Science* **2006,** *311,* 467.
31. Galston, A. W. *Annals New York Acad. Sci.* **1972,** *196,* 223–235.
32. Crouch. *Plant Cell* **1990,** *2,* 275–277.
33. Gray, F. D. *The Tuskegee Syphilis Study;* New South Books: Montgomery, AL, 1998.
34. Jones, J. H. *Bad Blood: The Tuskegee Syphilis Experiment;* Free Press: New York, 1993.
35. *Tuskegee's Truths: Rethinking the Tuskegee Syphilis Study;* Reverby, S. M., Ed.; University of North Carolina Press: Chapel Hill, NC, 2000.
36. Marshall, E. *Science* **1999,** *284,* 883–886.
37. Barinaga, M. *Science* **1999,** *286,* 1655.
38. Barinaga, M. *Science* **1999,** *284,* 1752–1753.

Supporting *JCE Online* Material

http://www.jce.divched.org/Journal/Issues/2008/Jun/abs796.html

Abstract and keywords

Full text (PDF)
Links to cited URLs and *JCE* articles

Supplement
Real and fictional case studies with discussion questions, including links to some additional resources