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ABCS OF TEACHING ANALYTICAL SCIENCE

Teaching research ethics: it takes more than good science to make a good scientist

Victoria L. McGuffin

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Why teach ethics?

As educators of graduate and postdoctoral students in analytical and bioanalytical chemistry, we recognize our responsibility to instill in our students a love of science and respect for its traditions. Without question, this includes an introduction to the scientific method, a broad scientific background, deep understanding of theoretical principles, instrumentation, experimental methods, statistical treatment of data, and so on. However, we may not recognize or acknowledge our responsibility to convey, with the same attention to detail, the moral and ethical standards of our profession.

Over the last decade, there has been a growing emphasis on ethical training in the undergraduate chemistry curriculum [1–5]. The American Chemical Society (ACS) Committee on Professional Training has developed guidelines [6] and many colleges and universities have already implemented these recommended programs and practices. However, the students who enter our graduate programs or pursue postdoctoral studies are not homogeneous in terms of culture or educational preparation. So there can be no expectation or reliance on prior experience and knowledge of ethical issues. Moreover, as most university research is performed by graduate and postdoctoral students, ethical instruction is essential to maintain the integrity and quality of the research enterprise. Several federal agencies, including the US National Institutes of Health (NIH) and National Science Foundation (NSF), have encouraged such training in the responsible conduct of research (RCR).

There is often a resistance or reluctance among scientific faculty members to the general concept of teaching research ethics. One common argument is that ethics cannot be taught. Students either have moral principles or they do not, and there is little we can do at this late stage to alter their essential character. However, this argument is lacking in foundation. Although the most widely publicized cases of scientific misconduct can be attributed to people who are routinely and pathologically unethical in their behavior, these are not the most common cases. Rather, most instances of misconduct originate from ordinary people under ordinary circumstances who make uninformed or poor ethical decisions. Both of these deficiencies can be addressed by appropriate instruction in research ethics. Uninformed decisions can be precluded by providing information on the expected standards of behavior; poor decisions can be averted by providing an opportunity to develop and exercise logical ethical thought.

Another objection is that faculty members in chemistry do not have training in teaching research ethics. However, it is important to point out that most of us do not have formal training in teaching any subject—including chemistry! We have learned to teach chemistry by example, that is, by observing our own professors and colleagues, imitating their strengths and avoiding their weaknesses. We can learn to teach ethics in the same way. With sufficient motivation, together with some basic training, ideas, and resources, chemistry faculty members are fully qualified to convey the ethical standards of our profession. Moreover, we may be the very best teachers of this subject because we are likely to make the subject practical, relevant, and not overly abstract. The teaching of ethics also focuses our own attention and awareness on this important subject, so that we more consciously "practice what we preach".

V. L. McGuffin (✉)
Department of Chemistry, Michigan State University,
East Lansing, MI 48824-1322, USA
e-mail: jgshabus@aol.com

Which ethical topics can and should be taught?

There are a wide variety of ethical topics that can directly or indirectly influence the professional development of graduate and postdoctoral students in analytical and bioanalytical chemistry. A list of such topics is given below, together with some potential issues for discussion. This list is not intended to be specific or comprehensive, but merely illustrative of the wide variety of ethical topics that might be considered as part of graduate training.

Data and record keeping

This broad topic may include fundamental questions such as who owns the data and other products of a research project or thesis, which data or other primary records must be collected and preserved, who is responsible for retaining these records and for how long, etc. It may also include issues related to responsible treatment of data, such as rejection or selective reporting of data, inaccurate or misrepresentation of data, treatment of digital images, etc. Several texts contain excellent discussions of this general topic [7, 8]. In addition, an older but still entertaining and informative book *How to Lie with Statistics* serves as an excellent resource [9].

Authorship

This topic may include fundamental questions such as who should be considered as an author of a paper, who should be acknowledged for their contributions, how is the order of authorship decided, what are the respective responsibilities of the first, corresponding, and other authors, who bears responsibility for the scientific content of the paper, etc. It may also include issues related to the format, content, and completeness of published articles, plagiarism or appropriating ideas, text, or figures without permission and proper citation, etc. Again, several books provide an excellent introduction to this topic [8]. In addition, many professional societies and scientific journals have published detailed descriptions of the expected standards [10–13].

Peer review

This topic may include issues related to the peer review of book and journal publications as well as grant proposals. Among these issues are participation, criteria of merit, timeliness and objectivity in evaluating the submitted manuscript or grant, confidentiality and anonymity, and avoidance of conflict of interest, whether due to personal relationships, scientific competition, or financial interest. Again, many professional societies, scientific journals, and granting agencies have published descriptions of the expected standards [10–12, 14–16]. With permission of the journal or granting agency, graduate and postdoctoral students may be involved directly in the peer review process to acquaint them with the underlying ethical issues.

Collegiality

This topic may include issues related to student/student relationships, such as cooperation and competition, conflicting expectations and priorities, disruptive behavior, distrust or disrespect, jealousy, etc. It may also include faculty/student issues, such as mentoring, fairness and impartiality in expectations and evaluations, impartiality in allocation of resources and opportunities, conflicting expectations regarding the content and completion of research projects or theses, switching projects or advisors, coercion or improper use of power, inappropriate intimate relationships, vacation and personal time, family obligations, etc. Finally, it may include faculty/faculty issues related to recruitment, mentoring of junior faculty, tenure process, cooperation and competition, collaborative research, etc. There are helpful books and other materials related to the management of research groups [8, 17] and collaborative research [18].

Human and animal subjects

Although not pertinent in all areas of analytical and bioanalytical chemistry, ethical training should include a brief overview of the ethical treatment of human and animal subjects. This topic may include fundamental questions such as what are the rights of human subjects, do animals have the same rights, do all animals have the same ethical standing or is there differentiation among, for example, fruit flies, mice, dogs, and primates. For human subjects, it may include the concept and responsibilities of informed consent, confidentiality, minimizing risk and harm, special considerations for research with children, persons with disabilities, and other vulnerable populations, and the role of institutional review boards [8, 19, 20]. For animal subjects, it may include the legal standards for laboratory animal care [21, 22], replacement of animal models, and refinement of experimental methods to minimize the number of animals required as well as their pain, suffering, disability, and death [8].

Other issues

Although conflict of interest was mentioned above with regard to the peer review process, there can be other instances of occurrence. For example, students and faculty may be involved in consultation or collaborative research with industry, which may invoke new issues related to confidentiality, patent rights, and financial interest. Alter-

natively, they may become involved in a start-up company associated with the commercialization of ongoing research efforts. The extent to which these activities restrict or inhibit the free dissemination of research results through presentations, publications, dissertations, or job interviews is an important ethical issue. There can also be instances of conflict of time and effort when outside activities, which may or may not be professionally related, begin to infringe on primary academic responsibilities [8]. Another appropriate area of discussion is the proper use of research funds, whether from federal sources or from industry, as well as the associated supplies and equipment. Finally, it is important to consider how and when to raise questions of misconduct, conflict of interest, etc. As noted above, this list is not all-inclusive and there are many other moral and ethical issues that are relevant in analytical and bioanalytical chemistry.

How can ethics be incorporated in graduate education?

There are a variety of ways to incorporate discussions of ethical principles and practices into graduate and postdoctoral education. This article will begin with the most informal and personal approaches and proceed to the most formal, organized, and institutionally sanctioned approaches. Depending upon the climate in each chemistry department and university, one or more of these approaches should be effective. It is important to recognize that, in the absence of departmental or university guidelines, it is the responsibility of the faculty member or principal investigator to provide ethical training to graduate and postdoctoral students under their supervision.

One of the simplest approaches is to identify "teachable moments", either while an ethical situation is occurring or very shortly after it has occurred. In these teachable moments, it is possible to focus the student's attention (either individually or in groups) on the specific issues: Who was impacted by the situation? How did the situation arise and how was it handled? What other options were available and what are the relative merits and consequences of each? How might the situation have been prevented? The advantage of this approach is that it addresses practical problems that students and faculty are most likely to encounter on a routine basis, such as data manipulation, plagiarism, etc. It also makes apparent the immediate and long-term impacts of ethical decision-making to both the students and faculty involved. The disadvantage is that students will not encounter all of the common ethical issues during their tenure, and there is no standardized or broad view of their ethical education.

Another simple approach is to provide copies of selected papers, chapters, or books to graduate and postdoctoral students during their orientation to the research group, department, or university. A few recommended materials are given in the following section. An advantage of this approach is that topics can be broadly selected to cover all of the important ethical issues and the materials can be kept by the students as a reference for continued use. This approach is easy to implement and likely to be supported by all faculty within a department, as it requires minimal time and effort. The disadvantage is that there is no ongoing effort to develop the logical skills of the students on ethical issues. So ethics is treated as a static, not dynamic component of graduate education. Ethics cannot be learned solely by reading a textbook to any greater extent than chemistry can be learned by this approach.

To overcome this limitation, it is desirable to introduce ethical discussions on a recurring basis throughout the tenure of the graduate and postdoctoral students. This can be accomplished by inviting guest lecturers in ethics, several times per year, as part of a regularly scheduled seminar or colloquium program. Again, this approach requires minimal time and effort by the faculty and, hence, is likely to be supported. Suitable invited lecturers can be identified from their presentations and publications and, following these initial contacts, from their subsequent recommendations of other active workers in the field.

Another way to accomplish this goal is for individual faculty members to include discussions of ethical topics in their regularly scheduled research group meetings. Although this requires more effort by the faculty member, it does not require the consensus and cooperation of other faculty. It also permits more flexibility in choosing the timing and topics for discussion, for example, issues of data ownership and record keeping can be discussed when new members join the group.

A more time-consuming, but highly effective approach is to add a separate course on ethics to the graduate curriculum. Such a course might consist of some lectures, discussions involving case histories, short writing assignments, group projects, etc. This requires that the faculty member(s) responsible for teaching the course feel sufficiently knowledgeable and confident in their ability to teach the topic effectively. To address this concern, it may be beneficial to organize the course jointly with a faculty member from the ethics or philosophy department who has more experience in these areas [23]. Alternatively, there are workshops for teaching research ethics that can provide the chemistry faculty member with the knowledge, resources, and skills that are needed. Some of these resources are described in the following section.

Another approach that has proven successful in undergraduate programs is to integrate ethical training throughout the curriculum. A few ethical issues of growing depth and complexity can be introduced in each lecture or laboratory course. However, this approach is less likely to be successful with graduate training, because the number, type, and sequence of courses is highly variable. Moreover,

it is not appropriate for training postdoctoral students. As an alternative, "short courses" can be offered periodically that focus on specific ethical topics. These short courses can be distributed throughout the students' tenure and, hence, can gradually develop their depth of knowledge and skills in logical thinking. This approach can potentially distribute the effort, responsibility, and involve more faculty in teaching research ethics. In addition, this approach can effectively be used to combine ethical training with other related topics such as safety training, good laboratory practices, and so on.

Finally, because of growing federal interest and involvement in this issue, university-sponsored programs in responsible conduct of research (RCR) can be organized. These programs are necessarily broad and nonspecific, addressing ethical issues in all areas of the social and physical sciences as well as engineering. As such, not all topics may be relevant for chemistry students and not all relevant topics may be included. There is also a tendency for students to view such programs as "hoops", that is, obstacles to be endured and overcome, and not really relevant to the daily conduct of their research. For this reason, it is especially important for chemistry faculty to remain connected with this important topic and not relegate the teaching of scientific ethics to others.

What resources are available?

There are many resources, old and new, that can assist and support us in teaching scientific ethics. The list of resources below is not comprehensive, but should be sufficient to provide ideas and inspiration.

Codes of conduct

Among the most important resources are the codes of conduct developed by our professional societies [24–29] and federal agencies [30, 31]. These codes express the fundamental standards of behavior that are expected of all scientists in our profession. In addition, there may be codes of conduct specific to each university. Graduate and postdoctoral students should be fully aware and familiar with the standards expected by their peers.

There are also a number of books that are helpful in delineating the expected standards of thought and behavior. Among these, the texts by Wilson [7], Bronowski [32], Medawar [33], and Grinnell [34] are especially useful.

Textbooks

In addition to those mentioned above, some texts provide more detailed resources for the teaching of scientific ethics [8, 35–39]. One of the most effective ways to introduce ethical principles is through the use of case histories. A case history may be based on factual circumstances but, more often, is a fictional situation intended to promote discussion of specific ethical principles. An example of such a case history is given in Fig. 1. The best of these texts also include commentaries and guidelines for leading student discussions of case histories.

Workshops and conferences

There are several workshops for faculty members that are designed to provide the tools and techniques as well as the confidence necessary to teach research ethics. For example, faculty from the Poynter Center for the Study of Ethics at Indiana University hold an annual Teaching Research Ethics Workshop, the next of which is scheduled for 13–16 May 2008. Information and other resources can be found on their website [40]. Another option is the Workshop on Teaching Survival Skills and Ethics, sponsored by the US Department of Health and Human Services (DHHS), Office of Research Integrity. This workshop is presented by faculty from the Survival Skills and Ethics Program at the University of Pittsburgh [41]. The next workshop is scheduled for 8–13 June 2008. Other workshops on specific topics are regularly sponsored or co-sponsored by the DHHS Office of Research Integrity [42] and the Responsible Conduct of Research Education Committee, Association for Practical and Professional Ethics [43].

There are also a number of conferences on research ethics. Of particular importance is the First World Conference on Research Integrity, which was held in Lisbon, Portugal, on 17–19 September 2007. This conference was jointly sponsored by the DHHS Office of Research Integrity and the European Science Foundation. The invited lectures can be downloaded from the conference website [44]. This conference is intended to provide a global forum to discuss ethical issues of broad interest in the sciences.

Web resources

A number of excellent web resources have been developed over the last few years. In particular, tutorials on many of the topics mentioned above have been developed by the National Institutes of Health [45], the National Academy of Engineering in conjunction with Case Western Reserve University [46], and the DHHS Office of Research Integrity in conjunction with the University of Montana [47]. In addition, a number of universities have developed online training modules, including University of California–San Diego [48], Columbia University [49], University of Michigan [50], University of New Hampshire [51], Northern Illinois University [52], North Carolina State University

SAMPLE CASE HISTORY:

Bob is a senior graduate student in the research group of Professor Chris Atkins. When reading the introductory chapter of Bob's dissertation, Professor Atkins thought that some of the text sounded very familiar. Upon further investigation, she found that it bore striking resemblance to the literature review of an NSF proposal that she had reviewed several months earlier with Bob's assistance. Although the wording was not verbatim, all of the key concepts, organization, and references were the same as the grant proposal. When she questioned Bob about it, he replied that he did not see that there was a problem since he had not directly copied the grant proposal. He would have found the same references through his own literature search, so he was just saving some time by using the grant proposal as a source.

Questions for discussion:

1. What ethical problem(s), if any, are represented in this situation?
2. Who might be affected or have a vested interest in these ethical problem(s)?
3. After this conversation with Bob, what might be the possible responses or courses of action by Professor Atkins? What are the potential outcomes of each action? Which action would you recommend? Why?
4. How would the situation be different if the source material were a published review paper rather than a grant proposal? How would it be different if the review paper were published by Professor Atkins and her group?
5. How might this situation have been avoided?

Fig. 1 Specific ethical principles introduced using a sample case history

[53], University of Pittsburgh [54], and others [55]. Some of these training modules are interactive with a combination of activities and quizzes to evaluate progress, while others are simply reading material. Some require registration, while others are openly accessible. These online modules are useful for training graduate and postdoctoral students, but should not replace didactic interaction with faculty.

These websites, as well as many others, provide bibliographies and other materials for learning about and teaching research ethics. In particular, the bibliographies compiled by Sweeting at Towson University [56] and by the American Association for the Advancement of Science with the DHHS Office of Research Integrity [57] are detailed and comprehensive. Case histories and commentaries have been compiled by Schrag at the Association for Practical and Professional Ethics [58]. Finally, the Poynter Center at Indiana University [59] and Boston College [60] provide convenient links to various ethics programs and resources.

Other materials

In addition to the resources described above, a variety of other materials have been developed. Audio and video presentations of case histories can be an effective means to convey some ethical issues [61, 62]. In addition, some case histories have been written as scripts for live performance and role-playing exercises [63]. Several websites have guides and detailed advice for using these resources and others in the teaching of scientific ethics [64, 65]. Finally, newsletters can be helpful to keep abreast of new developments and changes in the applicable policies. The newsletters of the DHHS Office of Research Integrity can be accessed on their website [66]. In addition, some universities have published ethics newsletters and other periodicals [67, 68].

What are the benefits of teaching research ethics?

As with any new endeavor, it takes an initial investment of time and effort to begin teaching research ethics to graduate and postdoctoral students. However, the results are unquestionably worthwhile. With a little instruction, students become more knowledgeable about ethical issues and more aware of the many circumstances in which they arise. With further instruction, their skills of assessment and logical reasoning improve and they begin to make better ethical decisions. They are able to see how these skills can be practically applied, both now and in the future of their scientific careers. They are able to support one another in doing the right thing. All of these positive changes lead to an academic environment of greater honesty and integrity, which benefits us all.

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experience and knowledge of resources is limited to those produced in the USA and, to a much lesser extent, in Canada. I regret my inability to direct you to similar resources in Central and South America, Europe, Asia, Australia, and Africa. If any colleagues from these areas are familiar with local standards and resources, please do not hesitate to contact me so that we may work together to compile a more comprehensive list.

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Victoria L. McGuffin is Professor of Chemistry at Michigan State University, where she is actively involved in the formal and informal education of graduate and postdoctoral students. Her primary research interests are in the thermodynamic and kinetic basis of liquid chromatography and electrophoresis. She is also interested in the development of novel laser-based detection systems for chromatography and electrophoresis, as well their practical application for forensic and environmental applications.