Research Skills and Ethics—A Graduate Course Empowering Graduate Students for Productive Research Careers in Graduate School and Beyond

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Research Skills & Ethics—A Graduate Course Empowering Graduate Students for Productive Research Careers in Graduate School and Beyond

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A number of professional organizations and educational leaders have raised a wide array of issues regarding the quality of graduate education and the fitness of Ph.D. graduates both in the USA and abroad to function effectively in a rapidly changing global economy (*1–6*). The issues include a need to improve students' creative thinking, achieve balance between specialization and breadth, facilitate industrial awareness, provide meaningful career counseling, and foster teamwork. There is also concern that entering graduate students need to be oriented in their new university and department and that efforts need to be made to acquaint them with the professional tasks of their discipline if we are to retain talented students (*7, 8*).

Consequently, it was surprising to find that few departmental or institutional efforts to improve the quality of graduate education in these areas have been documented (*9*). The University of Texas at Dallas Doctor of Chemistry program offers a unique approach in terms of both structure and degree offering by providing students with real-world industrial experience. However, this approach is viewed by many as radical and it requires enormous departmental and institutional support. Recently, in the *Journal of Chemical Education*, Joseph Bunnett described a course he feels should be a component of Ph.D. programs in Chemistry (*10*). "The Culture of Chemistry" teaches students the skills and methodologies needed to be successful in dissertation research and to achieve a productive career. Unfortunately, the course is imaginary.

In view of the renewed interest in graduate education, the strange silence in the chemical education literature regarding the graduate curriculum, and Bunnett's paper (*10*), I wish to report on a course we developed at Northeastern University in an effort to improve graduate education. The quarter-long course, entitled "Research Skills & Ethics", has now been offered for five years. It is required for all graduate students during the summer following their first year of graduate school. The overall goal of Research Skills & Ethics is to maximize success in graduate school and beyond by introducing students to the fundamental tasks in graduate education. This is accomplished by providing training in selected topics (ethics, laboratory safety and waste management, chemical information literacy, and communications), introducing students to the local experts and available technical resources, and acquainting them *early* with information on current and emerging career opportunities.

Course Structure

The course meets for one 2½-hour session per week, the standard format for graduate courses at our university, during the summer quarter (11 weeks, including finals) at the end of our students' first year in the graduate program. This is the point at which most of our full-time graduate students have completed most of their necessary course work and stand poised to begin full-time research in the laboratory. The average enrollment has been 10–12 for the past three years.

The topical syllabus for the course is outlined in the box. Extensive course notes are available on the World Wide Web (*http://www.chem.neu.edu/Courses/3500/3500guid.htm*). Half of the lectures are given in partnership with local experts including the chemistry librarian, a technical grant writer, and

Chronological Topical Syllabus

Weeks 1 and 2—Ethics in science
Assignment 1: Group oral presentation of ethical situation from *On Being a Scientist*
Assignment 2: Individual reflection on a past ethical dilemma

Weeks 2 and 3—Laboratory safety, with Environmental Health and Safety Office
MSDS
Gloves
Chemical storage
Waste management
Assignment 3: Examination of research lab safety practices in current research lab

Week 4—Chemical literacy, with Science Librarian (Part 1)
Chemical Abstracts
Online literature searching
Assignment 4: Student selection of final project presentation topic and literature search

Week 5—Preparation and delivery of effective scientific presentations, with Media Services
Posters
Oral presentations
Assignment 5: Personal reflection on useful strategies for effective presentations

Week 6—Chemical literacy (Part 2)
Format of technical paper
Format of patent
Reviewing
Assignment 6: Preparation of cover letter and technical article

Week 7—Grants, with technical writer from Sponsored Projects Office
Assignment 7: Peer-review of technical articles from Assignment 6

Week 8—Good experimental design
Research notebook
Experimental design
Statistical analysis of data
Ethics of experimentation
Assignment 8a: Preparation of response to reviewers

Week 9—Career development issues
Resumé, cover letter, business card
Interviewing—the ethics of job hunting
Research careers in industry, government, and academe
Assignment 8b: Preparation of business card, professional resumé, and cover letter to prospective employer of student's choice

Weeks 10–11—Final in-class individual oral presentations (20 min each)

an environmental health and safety officer, to ensure that the students become familiar with the university resources and technical staff best equipped to ensure their success. The course instructor delivers the formal lectures, facilitates class discussions, and grades the weekly assignments (see below). Owing to difficulties in meshing the busy schedules of so many individuals, the sequence of lectures listed in the box sometimes varies. However, most topics are independent and self-contained. We have had little difficulty in rearranging the lecture schedule when necessary to accommodate the schedules of the local experts.

To ensure that students make the proper functional connections, there are eight homework assignments (see box). Each assignment is designed to encourage students to reflect on and make use of what they learned in the previous week's lecture, and when appropriate, to network or make connections with a local expert and gain confidence and facility using available technical resources. A secondary objective of the weekly assignments is to give students an opportunity to practice their spoken and written communication skills. A significant number of the assignments are writing exercises such as preparation of a technical paper, reviewer comments, cover letter, and resumé. All are representative of the types of writing projects students will encounter in their professional lives whether in the academic, industrial, or government sector.

We place a strong emphasis on writing for two reasons. First, we have a high percentage of foreign graduate students (50% on average for 1997–1999) in our graduate program. Early training in technical writing is critical for these students, since their cultural values often differ from those of U.S.-trained students in terms of the value, purpose, and pedagogy in writing (*11*). Second, we have found that the majority of beginning graduate students simply do not appreciate the importance of good writing skills for their present and future career success, nor are they aware of the styles unique to scientific writing.

Lectures are supplemented by a lengthy list of required and collateral reading material.[W] *The ACS Style Guide* (*12*), *On Being a Scientist* (*13*), and Martha Davis's book *Scientific Papers and Presentations* (*14*) are required reading. At the beginning of the course students are given a packet containing most of the collateral articles and a number of useful booklets. For example, Chemical Abstracts (CA) provides at no cost a very useful booklet entitled *How to Search Printed CA* and a colorful "cheat sheet" for CA searching. The ACS Office of Society Services provides complimentary copies of their useful career resource booklets, including *Targeting the Job Market*, *Tips on Resume Preparation*, and *The Interview Handbook*.

Ethics

Because ethics is fundamental to the spirit of scientific inquiry, the course begins with a two-week discussion of ethics and research integrity. A study of four academic disciplines including chemistry found that the average graduate student is exposed to misconduct by two to five graduate students or faculty members during his or her tenure (*15*). Therefore we discuss the kinds of ethical dilemmas we believe the students are most likely to encounter: plagiarism, fabrication, and falsification of data. We do this by first presenting the Office of Science and Technology Policy's definitions of these terms. We then look at examples of allegations of each kind of misconduct: Leo Paquette (plagiarism) (*16*), David Baltimore/Imanishi Kari (fabrication/falsification) (*17, 18*), and Francis Collins (falsification/fabrication) (*19*). Next we examine the issues of openness, conflict of interest, personal misrepresentation, and assignment of credit. At this point, students are asked to form groups of 3–4 and to select an ethical scenario from the National Academy of Science's booklet *On Being a Scientist* (*13*). During the second class period, each team presents and discusses the scenario it selected and guides the class in answering the questions posed in the booklet as well as questions of their own.

Our discussion of ethics does not end here. Since ethics is incontrovertibly interwoven throughout the practice of science, we revisit ethics in subsequent lecture discussions on laboratory safety, technical papers, grants, experimental design, and career development.

Lab Safety

In week 3, laboratory safety is examined. We believe that early safety training is very important because few American colleges and universities provide formal safety training for chemistry majors (*20*) and because of the significant potential for danger posed by the fundamentally independent nature of graduate research. The safety training is given by staff from the campus Office of Environmental Health and Safety. It provides instruction on MSDS, personal protection including proper glove selection, spills, waste management, and lab accident and emergency procedures. A representative from Fire Safety also usually participates and gives students hands-on experience using fire extinguishers.

Since it is difficult to provide meaningful training in $2\frac{1}{2}$ hours in the wide range of hazards (high voltage, radiation, laser, high pressure, cryogenic, etc.) presented by the modern research laboratory and since students may work in isolation in small research groups, this week's writing assignment requires students to reflect on safety practices in their own laboratory. It also provides an opportunity for meaningful dialogue among students, their research advisors, and the Office of Environmental Health and Safety regarding concerns that individual students have about their research projects or research laboratories.

Information Literacy

Information literacy, specifically the retrieval and critical evaluation of chemical information, is emphasized in the course. During week 4, the class moves to a computer teaching laboratory in the library where the chemistry librarian introduces the bibliographic resources available in printed form in the library and on the desktop through the World Wide Web. Among the resources demonstrated are UnCover, Medline, Chemical Abstracts, and SciFinder Scholar. In the last few years, strong emphasis has been placed on online databases, literature-searching resources, and discussion of effective strategies for literature searching. To ensure that students begin to practice their new-found information retrieval skills they are asked to identify a presentation topic for their final course presentation and to use their new tools and skills to prepare a bibliography. During the second half of the session,

the class begins work on the assignment with assistance from the chemistry librarian when needed.

Public Speaking

During week 5, the class moves across campus to Media Services, where a graphics design specialist instructs students on how to use the wide range of resources available to construct effective presentation materials such as slides, transparencies, or posters. The topics discussed in this lecture include the general format for an oral presentation, the basics of good graphical design, and tips for the preparation and delivery of an effective talk. To consolidate their knowledge, students are asked to reflect on past presentations and write a brief paper in which they identify three strategies they intend to apply in order to make their final course presentation effective.

The Coffee Project

An important element of graduate work centers on the preparation and publication of technical articles. Few first-year graduate students have experience reading technical papers. Even fewer have participated in the publication process and know how to construct a quality technical paper and get it published. The next week (week 6 this year) class discussion turns to the form and content of the technical paper and patent and to publication and patent application processes. Since there is no adequate substitute for experience, students simulate the publication process through a multi-week project that we call "The Coffee Project", in which they write a paper and then participate in all aspects of the review process as both authors and reviewers.

During a midclass break, self-identified student teams go on "field-trips" to purchase several cups (samples) of different brewed local coffees (black—no cream, no sugar). Half of the class then acts as a taste-testing panel, determining which coffee samples they prefer and why. The other half of the class uses an inexpensive, robust, portable ISFET pH meter (IQ Scientific, San Diego) to measure the pH of the ice-cooled coffee samples. Testing is carried out in class and requires approximately 45 min. Data are pooled and tabulated on the chalk board at the end of the class period. Each person is asked to prepare his or her own technical article using the class data and to prepare a suitable cover letter for transmission of the article to the selected journal, in this case, *Journal of the American Chemical Society*. The next week, papers are peer-reviewed by every student and the instructor according to the *JACS* reviewer guidelines. The following week, everyone is provided with the reviews and is asked to make any necessary corrections and to draft a thoughtful response to three reviewers selected by the instructor. The response and a suitably revised manuscript are then reexamined by the instructor and a final disposition regarding the manuscript is issued.

We have found it advantageous for everyone to participate in the same project. This ensures that each student has first-hand knowledge of what was done and how it was done. We emphasize pH because it is a rudimentary concept understood and universally appreciated by graduate students irrespective of their chosen specialization. The study of coffee, a popular beverage, was chosen because our students find it entertaining. The project design is relatively simple, no expensive reagents or instruments are required, and there are no significant hazards. These characteristics allow students to concentrate on the technical aspects of publication. They are able to focus on writing the paper and to be more authoritative and critical when preparing their reviews.

Grant Writing

Most entering graduate students know little about how research is financed at research universities. We believe it is important to help them understand the system that underwrites their studies and their graduate advisor's research programs and to enable them to take advantage of available fellowship opportunities. Accordingly, in week 7, a scientific technical writer from our Division of Sponsored Projects Administration discusses extramural support. The discussion centers on the questions of who provides support for research (government, foundations, etc.), how to identify suitable opportunities, what specifically grants provide in terms of support, how to apply for grants, and what, if anything, researchers are expected to provide in return for the support of their research projects. To provide some experience in grant preparation, for several years we asked students to prepare modified NIH postdoctoral fellowship applications. However, on the basis of student feedback (few of our graduate students pursue postdoctoral positions upon graduation), this assignment was dropped from the course.

General Skills

By week 8, most graduate students have begun to do experiments in their new research groups and are eager to learn how to work efficiently and effectively. It is therefore appropriate at this point to discuss with students a variety of topics relevant to their work in the laboratory, such as the basics of good experimental design, good scientific record keeping, and statistical analysis of data. We also revisit our earlier discussion of ethical behavior and emphasize the importance of maintaining high ethical standards when conducting experiments, analyzing data, and reporting results.

Career Development

Many of our graduate students go on summer industrial internships or participate in research funded by companies at some point during their graduate careers. Consequently, we make a strong effort to educate our students concerning career opportunities in industry and career development issues *early* in their graduate careers. During week 9, one-third of the class period is devoted to a comparison of the advantages and disadvantages of scientific careers in academe, industry, and government. The remainder of this session focuses on a discussion of the nuts and bolts of job/internship hunting—how to use business cards; how to effectively write resumés, cover letters, and thank-you notes; developing interviewing skills and awareness of business etiquette; and, once again, ethics.

Final Oral Presentation

The course culminates in a 20-minute oral presentation by each student during the final two weeks of the quarter.

Students make a presentation on a topic of their choice usually related to their Ph.D. research. The assignment allows them to share the first fruits of their research and to apply the information literacy and presentation skills that they have developed throughout the course. The students must prepare and distribute to everyone an abstract, a set of handouts, and an up-to-date bibliography, as well as deliver their talk and successfully field questions from the audience.

Grading

Grading for this course contains both individual and group (ethics presentation, coffee project) elements. The final individual oral presentation, described above, is worth 20% of the course grade. The eight assignments, each worth 10%, account for the remainder. Assessment and written feedback are provided each week to help students to improve their writing. Grades usually range from A to B–; about one-third of the class earns an A or A–.

Student Response/Assessment

While it is still too early to evaluate the long-term impact of this course on graduate student retention and postgraduate career success, all available feedback so far indicates that both students and faculty have benefited from it. In the last two years, two graduate students from other departments (chemical engineering and pharmacy), a student from the part-time masters program, and two postdoctoral students have chosen to participate in the course. This interest from other departments, industry, and postgraduates is circumstantial evidence of the popularity and utility of this course from a student perspective.

Student course evaluations for the last three years have been consistently high (rating of 4.2 ± 0.7 out of 5). Responses indicate that students feel they have learned a great deal in the course. One student wrote: "I was actually surprised by how much I learned this summer. Even the topics that were not so useful to me (because of my background) were important to present to the students. It was good to do this before anybody gets into their research at all."

We attempt to survey students annually after they complete the course. Past students remain very positive about the course. Several have indicated that they continue to make use of the course lecture notes that are posted on World Wide Web. One student commented: "Yes, it has become a guide for my research. It is the knowledge that I can't possibly learn from other resources." A postdoctoral student wrote: "Even it is helpful for me, who already had a Ph.D. degree."

Final Thoughts

This course provides many advantages to programs seriously interested in meeting the myriad challenges facing graduate education today. It ensures that students are well grounded in the fundamental features of their graduate education and provides a formal mechanism for instruction in lab safety, ethics, and experimental design. Students become acquainted with the personnel, facilities, and other resources available to assist them and to help them deal with problems that may arise. Since the information is provided in the formal classroom setting by one instructor, the quality of training the students receive, at least at a fundamental level, is the same regardless of their graduate advisors or areas of specialization. Finally, the approach ensures that *early* in their graduate education students understand the career opportunities available to them and have the skills needed for success in professional life.

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[W]Supplemental Material

A list of required and collateral reading material for the course is available in this issue of *JCE Online*.

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