Sci Eng Ethics (2007) 13:117–127
DOI 10.1007/s11948-006-0004-0

ORIGINAL PAPER

A course treating ethical issues in physics

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Received: 30 July 2005 / Accepted: 10 December 2006 /
Published online: 24 January 2007

Abstract A course focusing on ethical issues in physics has been taught to undergraduate students at Eastern Michigan University since 1988. The course covers both responsible conduct of research and ethical issues associated with how physicists interact with the rest of society. Since most undergraduate physics majors will not have a career in academia, it is important that a course such as this address issues that will be relevant to physicists in a wide range of job situations. There is a wealth of published work that can be drawn on for reading assignments.

Keywords Physics · Ethics education

Background

Physicists have had a significant role in the development of society and in the shaping of world events through a myriad of advances with technological applications. At times the study of physics is viewed as esoteric, but in fact much of what is known about physics has an impact on our daily lives. Some developments appear gradual, such as improvements in the understanding of solid-state physics leading to faster and more powerful computers; other developments burst on to the scene with suddenness, such as the development of the first nuclear weapons.

While physicists have recognized the importance of their role in society, they have tended not to study in any formal way the ethical implications of

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this role. Historically, courses in scientific ethics have been much more likely to be associated with the life sciences rather than the physical sciences. This is not to say that physicists do not care about these issues. A casual perusal of books written by physicists and articles in publications such as *Physics Today* and *Bulletin of the Atomic Scientists* reveals deeply held concerns regarding a number of important issues. However, most physicists have been content with these issues being addressed outside the mainstream of their traditional academic focus.

There are also numerous ethical issues relating to research conduct and other professional activities that have come to the forefront in recent years. Outright fraud was an issue in the highly publicized cases of a Lawrence Berkeley Lab physicist [19] and a Lucent Technologies physicist [12]. Less often discussed are subtler issues related to fair representation of data and appropriate standards in publications [23]. Here again, it has been the custom in the physics community to address these issues through discourse in the community rather than through formal education.

The danger in this approach is that important issues can be overlooked by all except those on whom the negative impact is greatest. This point was particularly well illustrated in a recent survey taken by the American Physical Society Task Force on Ethics where the following observation was reported: ‘‘Particularly shocking to the task force was how often the words ‘abuse’ and ‘exploitation’ were used to describe the treatment of graduate students’’ [9]. This survey showed that less than 10% of ‘‘junior members’’ of the physics community (i.e., those who had received their Ph.D. within the past 3 years) had taken a formal course dealing with ethics. While a survey of physicists taken 10 years ago indicated some significant (but by no means unanimous) support for courses dealing with ethical issues in science [24], it would appear that there has been limited progress in actually introducing such courses in the physics community.

A number of events have converged in recent years that make it worth considering broader use of formal education in ethics within the scientific community. Accrediting agencies are increasingly looking for an indication that students are aware of the societal implications of science. For instance, the National Science Teachers Association recommends that high school physics teachers ‘‘be prepared to lead students to understand...[a]pplications of physics in environmental quality and to personal and community health’’ [16]. The Accreditation Board for Engineering and Technology states that ‘‘Engineering programs must demonstrate that their students attain...an understanding of professional and ethical responsibility’’ [1]. Further interest in ethics education has been spurred by the Office of Research Integrity and the National Science Foundation, through both regulatory and funding activities. It is in this context that it would appear to be useful to summarize experiences at Eastern Michigan University (EMU) with ethics education in physics. A major barrier to teaching a course dealing with ethical issues in physics is the lack of a textbook designed specifically for this role. It is hoped that by providing an overview of the course as it is taught at EMU, this paper will highlight some of the many resources that are available, if presently only in scattered form, and promote discussions of the characteristics of a good physics-oriented ethics course.

Course content

"Ethical Issues in Physics" was introduced in 1988 as an elective in all undergraduate and graduate level programs in physics at EMU. It is a discussion-oriented course meeting 1 h per week for one semester. The goal of the course is to increase the likelihood that students will take a thoughtful approach to analyzing ethical issues that may arise in a physics-related job. Specific objectives include making students aware of ethical standards in physics and related fields, making them aware of why the standards exist, and helping them to understand how to apply the standards, including in cases where one or more standards appear to conflict.

Enrollment in the course fluctuated substantially in the first few years, sometimes representing a significant portion of advanced undergraduate students and other years attracting just a handful of students. Although graduate students (at the masters level) have taken the course from time to time, this has not been the focus of the course. In response to accreditation requirements for the secondary education program in physics and out of the belief that students benefit from a structured approach to ethics education, the course has come to be required in all undergraduate programs in physics at EMU. This ensures a steady population of students for the course, and class evaluations (discussed in more detail below) seem to indicate that they do not resent this requirement.

The first few times the course was taught, the focus was on the university culture. Issues discussed included responsible conduct of research in an academic environment and the interactions of academic physicists with the rest of society. Course evaluations pointed toward the need for a broader based approach. In fact, a national survey of college seniors (class of 2003) majoring in physics indicated that just 39% had as a career goal a university position [14]. Coupled with the fact that not all who initially pursue that goal will achieve it, it is clear that the majority of physics majors do not wind up in university-level academic positions. The course evolved to reflect this fact. Issues related to physicists working in industry and to high school teachers were introduced. The codes of conduct studied were expanded to include the related fields of engineering and chemistry.

As presently structured, the course begins with an overview of scientific ethics based on the work of philosopher/ethicists such as David Resnik [17]. This overview provides a framework for examining a number of specific codes of conduct and is followed by a study of the American Physical Society Guidelines for Professional Conduct [26], The American Chemical Society's Chemist's Code of Conduct [27], and a code of ethics from the engineering profession.[1] Class discussion typically revolves around comparing and contrasting the codes and discussing how the different roles played by these codes impact their structure. For instance, while an engineer who violates an engineering code of conduct is subject to loss of license, the same is not true for a physicist who violates the APS code of conduct. The reason for the standards—how they benefit science and society—comes out through more detailed discussions in the ensuing weeks on topics listed below.

The remainder of the course is devoted to discussion of issues divided into two broad categories: interactions within the scientific community and interactions between scientists and the rest of society. To the greatest extent possible, these discussions are grounded in real events involving physicists as opposed to fictional case studies. Using real events helps to emphasize the relevance of the issues and it also develops within the student an appreciation for the importance of having access to sufficient information before drawing a conclusion. Relying on real cases allows one to seek further information if required, a process not possible with a static, fictional case study. There are disadvantages, however, to using real events. Among them is that well-documented real events often involve well-known physicists, perhaps leading students to think that these are events not likely to be encountered in the lives of ''ordinary'' physicists. Careful management of classroom discussion can help maintain the relevance of these events.

Interactions within the scientific community

Among the issues involving interactions within the scientific community, one that cuts across the careers of all physicists is how to appropriately manage and interpret data. Irving Langmuir has described a number of historical incidents in physics where data collection and interpretation has been very suspect [11]. At the same time, the Millikan oil drop experiment presents a good opportunity to discuss the practical side of data-related issues. Much has been written about Millikan's lab notebooks and how they relate to published papers. Ullica Segerstrale gives a good overview of both the points of controversy and the ongoing debate [21]. Mansoor Niaz and Maria Rodriguez discuss how the controversy has been handled in textbooks [15]. A focus on the question of when data should be reported and when it can be dropped from consideration helps keep the discussion relevant, particularly in connection to lab reports the students write in some of their other courses. Variations on the Millikan oil drop experiment are quite commonly performed at the undergraduate level; students with direct experience with the experiment will have more appreciation for the challenges Millikan and Fletcher faced in performing the experiment [8]. Students' perspectives initially range from the unrealistic ''you should always publish all of your data''

[1] The Online Ethics Center for Engineering and Science at Case Western Reserve University maintains copies of relevant codes on its web site, www.onlineethics.org.

to the acknowledgment of suppressing ‘‘bad’’ data in their own lab reports. A reasonable goal is moving the students towards an appreciation of the role of scientific judgment in deciding what data to report.

A second set of issues revolves around publication practices. Many students have no idea of the process a paper moves through to be published in a scientific journal. An understanding of this process is valuable not only for those whose career will include publishing their own papers, but it will also be valuable for those who will teach science and those who will rely on published work. Marcel LaFollette has written a useful book on publishing in the scientific community, excerpts of which can be used to bring out a number of ethical issues in publication [10]. It is important for students to recognize that even though there is a peer review process in place, it does not follow that one can always rely on papers to be accurate and to convey the best available understanding of the current state of a given field. Ethical obligations of authors (citing previous work, fairly representing data) and of peer reviewers (maintaining objectivity, disclosing conflicts of interest, preserving confidentiality) are also usefully addressed. The importance of these standards to the health of the physics community, while readily apparent to the typical faculty member, may not be obvious to students.

Although some aspects of his commentary may now be dated, David Mermin has raised a number of interesting points regarding publishing in physics [13]. Among these is the rapid increase in the number of publications, spurred in part by the effort of some physicists to develop as lengthy a publication list as possible using, in some cases, ethically dubious means. Widespread concern over the rise in the number of publications has sparked efforts by funding agencies such as the National Science Foundation to develop schemes to emphasize quality over quantity in evaluating a publication record. This response in and of itself provides an interesting illustration of how the scientific community can respond to situations that have a tendency to facilitate unethical behavior by restructuring the rules by which the community operates.

While plagiarism can be considered as a subtopic under publication issues, it actually has broader implications. It has become apparent that some students do not understand the importance of appropriately citing information, text, and figures obtained from internet sites. An ethics course presents an opportunity to discuss these issues in the context of the students’ current role as paper writer, and in their possible future roles of research paper author or classroom teacher. There are numerous university-maintained websites that provide guidance on how to avoid plagiarism [20].

A topic that many physicists do not recognize as relevant is that of research involving human subjects. Some research, especially in biophysics involves humans or human tissues. Less obviously, physicists involved in taking surveys or performing educational research are, more than likely, using human subjects for their research. As such, their research design must be reviewed and approved by a human subjects review committee prior to conducting any research that they intend to disseminate. For instance, before student evaluations of the course under discussion here were reviewed in preparation to write this paper, a research plan was submitted to and approved by EMU's Human Subjects Review Committee. That plan demonstrated that none of the information extracted from the evaluation forms was likely to breach the confidentiality implied in the student evaluation process.

Interactions between scientists and society

Interactions between scientists and society at large are often not addressed, or not addressed in a significant way, in courses focusing on responsible conduct of research. However, these issues are important in a more broadly defined ethics course. In general, it is useful to investigate the impact of scientific research on society, how scientists use resources that may be provided by society, and how scientists communicate with society.

Caution is needed when addressing the impact of scientific research on society. It is too easy for discussions to drift into public policy. For instance, the Strategic Defense Initiative, a product of the 1980s, was harshly criticized by some in the physics community but endorsed by others [22]. An inside perspective on some of the controversial issues is discussed in an article by Deborah Blum [3]. While a classroom discussion of whether or not SDI should have been pursued is interesting and lively, it may miss the underlying ethical principle: what one *chooses* to do research on should be consistent with what one believes is beneficial to society. There are numerous other historical incidents that illustrate this point. Perhaps the most studied incident is the Manhattan project. Many physicists sufficiently well known to have written autobiographies describe their experiences in this project [2, 25]. Such first hand insight is invaluable in illuminating how one considers the impact of research on society.

A second point to make regarding one's research is that the quality of the research affects not only one's reputation as a scientist but can also affect society at large. For instance, there is much research being performed by people in the physical sciences that is not particularly flashy but nonetheless can have a significant impact on public policy decisions. A case in point is research done by United States Geological Survey scientists on environmental issues related to the possible use of the Yucca Mountain site for nuclear waste storage. Recent evidence that some of that research may have been falsified serves as a reminder that objectivity in reporting such data is important in the short term, for providing the proper context in which to make public policy decisions, and in the long term, to maintain the credibility of scientists [5].

Safety is a third issue related to one's research with implications for science–society interactions (as well as for interactions within the scientific community). Proper attention to safety issues can impact not only those who work in laboratories but also those who may be indirectly affected by research through laboratory visits, hazardous waste disposal, etc. The physicist in academia can be particularly influential as a role model for safety in both instructional and research laboratories.[2]

A fourth issue directly related to one's research arises for most scientists who pursue careers at the University level: what are appropriate and inappropriate uses of grant money? While some of these issues are spelled out in formal federal or institutional regulations, other issues are not. It is clear, for instance, that it is inappropriate to use federal grant money to buy a car for personal use. On the other hand, it is less clear if it is appropriate to support a graduate student with a federally funded research assistantship while they are doing nothing but preparing for their comprehensive exam. Most universities have regulations regarding use of grant money that can make a starting point for discussion.

When examining how scientists use resources provided by society, it is useful to remind students that a significant part of their education is either directly or indirectly funded with tax dollars. That is, all scientists in this country have received some significant educational benefits from the tax-paying public. As a result, scientists should be willing to return the favor by on occasion providing assistance to the public when issues with scientific content arise. Issues of pressing, national importance such as energy policy are discussed within the physics community [4], and it is important that the results of these discussions are disseminated outside the community. Physicists can also play a role in local issues, such as giving curricular advice to K-12 schools. Feynman's description of his service on a textbook selection committee provides a nice springboard for discussion [6].

For those physicists who will interact with the non-physics community in a high school or college classroom, it is worth investigating topics related to the teaching of physics. While in practice many issues related to ethics of the teaching profession can be and are covered in education classes, it is nevertheless worth at least briefly discussing the importance of maintaining objectivity, confidentiality as appropriate, and respect for students in the classroom, particularly since education classes are often not required for teaching at the college level. It is also useful to discuss how to deal with pressures that tend to draw time away from teaching duties. Alvin Saperstein has an interesting discussion of these pressures in the university environment [18].

It is not at all uncommon for a physicist or engineer in industry to gradually migrate into positions that emphasize administration more than science or engineering. The codes of ethics for scientists and engineers differ from the standards for managers. While not trying to portray one as better than the other, loosely speaking scientists endeavor to get the answer right and management endeavors to get tasks completed on time and under budget. A point of common ground is that successfully completing a task generally requires getting the answer right. Nevertheless, scientists and engineers who move into

[2] A good instructional laboratory safety manual can be found on a web site funded by the Maryland State Department of Education at http://www.mdk12.org/instruction/curriculum/science/safety/physics.html

management face a different set of pressures, and it becomes a challenge to these individuals as they try to decide if they are speaking as a scientist or a manager. This conflict is well illustrated by the events leading up to the Challenger accident [7].

There are, of course, a number of other issues that could easily be addressed in a course of this nature. However, past experience has shown that time does not permit the inclusion of more topics than already discussed, and in fact covering only those mentioned so far is a challenge in a course that meets just 1 h a week.

Course structure

Over the years, a variety of approaches have been tried in this course, but common to all approaches is heavy reliance on classroom participation and discussion. The goal is to give the students practice working through ethical issues and to gain confidence in discussing them openly with their colleagues. For class sizes up to about a dozen, sitting around a long conference table has been an effective arrangement. Sometimes, special effort is required to ensure participation by all, such as basing part of the class grade on participation in the discussions or limiting individuals to three contributions in any one class period. When a class has more than a dozen students, it becomes impossible for all students to participate in the discussion in a meaningful way. Under these circumstances, it has been effective to break the class up into discussion groups of four to five students each. After a brief introduction to the topic, students enter into small group discussions guided by a list of questions or topics to consider and supervised by the instructor who roams from group to group. In the last 15 min of class time, the class is brought back together and the instructor facilitates an exchange of ideas among the groups. Varying the make-up of the discussion groups from 1 week to the next helps expose students to a wider range of perspectives than they would get if they were allowed to choose their own discussion partners.

Students prepare for each week's class by doing assigned reading, and the reading component can be enforced either by monitoring in-class discussions or by giving short reading quizzes. Additional writing assignments are generally desirable in order to remind the students that analysis of ethical issues can be well thought-out and logical, and that it is important for scientists to be able to communicate coherently in writing. Another assignment that has been employed regularly is participation in a panel discussion. The topic can be instructor chosen to ensure appropriateness, and it can also be tailored to the specific interests of panel members. For instance, a group of students who intend to pursue Ph.D.s in physics might be assigned a topic related to publication practices, while a group of future high school teachers might be assigned a topic related to laboratory safety.

In developing writing assignments (stand alone papers, papers accompanying panel discussions, and final exams), making explicit the requirement that students refer to specific standards from appropriate codes of conduct encourages them to provide a more concrete analysis of ethical issues involved in a given situation. It also reinforces the importance of these codes. Even if their careers eventually take them away from physics, many professions have a code of conduct and it is useful to be in the habit of familiarizing oneself with the appropriate codes.

The final exam in this course has always been an essay. One format begins with the following:

> Instructions: Analyze the situation below from an ethical perspective. Discuss which specific standards of scientific, engineering, or educational ethics are relevant and how conflicts (if any) between the dictates of these standards should be resolved. Your discussion should also address what additional information would be helpful in reaching a decision on how to proceed, keeping in mind that there is a realistic limit on how much information one may obtain prior to making a decision.

After this paragraph, a suitable case study is inserted. The students are told ahead of time the nature of the final but not the details of the case study. They are also told the basis for evaluation, which includes their identification of ethical issues raised by the case study, their citation of relevant codes of ethics that address these issues, their discussion of the standards in the context of the case and how they propose to handle conflicting standards, if any, their identification of additional information which would be useful before taking action, and the overall organization of the paper. Laying out the standards for the students ahead of time helps reinforce the intent of this exam, which is that students produce an organized, thoughtful analysis rather than a piece of fluff.

Student reaction

Available data from anonymous student evaluation forms of all offerings of this course show that when asked "What is your overall rating of this course?", 40% of students responded "A", 41% B, 14% C, 2% D, and 2% F ($N = 83$). These results are fairly typical of physics courses at EMU, indicating that this course is just as acceptable to students as any other departmental offering. That is, this course can be integrated into an undergraduate program without being viewed as a waste of time by most students. Among the most common written comments were those expressing appreciation for the discussion format of the course. Among the more common negative comments were those from students who questioned the relevance of some of the topics. These comments were particularly prevalent among students planning to teach high school physics. The course has evolved in recent years to better address the concerns of this group of students. While the bulk of the evaluations indicated satisfaction with the course, there were a handful of students at the extremes. A few were not happy with being required to take the course while others thought that one credit hour was not sufficient time given the importance of the issues. Among the most satisfying comments were those of the form, "The course brought up many interesting situations and problems that I hadn't thought of before."

What has been learned

As the course evolved, the importance of knowing the career aspirations of the students became increasingly apparent. It is too easy for those of us in academia to teach students as if they are going to follow our footsteps. The majority will not, and the courses taught should reflect that reality. Students now fill out an information sheet, including career plans, on the first day of class, and topics and assignments can then be modified appropriately to reflect the likely interests of the particular mix of students.

As in any other physics course, students want at least some of the examples to be relevant. This presents a challenge since most of the real cases studied involve well known individuals, whose very status may make the case seem remote to physics students. An instructor can be useful in bridging the gap between the case study and the student through personal experiences. For instance, while Feynman wrote of his role on a statewide textbook selection committee, a role unlikely to be filled by any student in a given offering of this course, many academic physicists have given their professional advice on curricular issues to K-12 teachers or school districts. And while few scientists have the opportunity to be in the high profile position of science advisor to the president, all scientists have the opportunity to discuss technical aspects of public policy issues with friends and neighbors.

A common criticism of ethics education is that ethics cannot be taught in a single course; one's moral compass is set during childhood and a series of 1-h discussions will not change that. Changing a student's moral compass is, in fact, too much to ask of a one credit hour course. However, for the student who comes into an ethics course with the desire to do the right thing, the course can be an eye-opening experience. The purpose of this course is to help students understand what the ethical standards are, why they exist, and how to apply them in challenging situations. If, by the end of the course, students are able to analyze a situation based on relevant ethical standards, then that would indicate an educational success.

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