Sci Eng Ethics (2013) 19:535–543
DOI 10.1007/s11948-011-9338-3

ORIGINAL PAPER

Teaching Science and Ethics to Undergraduates: A Multidisciplinary Approach

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Received: 23 August 2011 / Accepted: 24 November 2011 / Published online: 3 January 2012

Abstract The teaching of the ethical implications of scientific advances in science courses for undergraduates has significant advantages for both science and non-science majors. The article describes three courses taught by the author as examples of the concept, and examines the disadvantages as well as the advantages. A significant advantage of this approach is that many students take the courses primarily because of the ethical component who would not otherwise take science. A disadvantage is less time in the course for the science; arguably, this is outweighed by the greater retention of the science when it is put into context.

Keywords Teaching · Ethics · Science · Engineering · Genetics · Race in human beings · Atom bomb

Introduction

The teaching of ethics as part of a science curriculum has received some attention of late (Dooley 2000; Berne and Schummer 2005; Passino 2005; Dawson 2009; Heely et al. 2010; Reilly and Strickland 2010; Alpay 2011; Ecklund 2011) but there is much more to be done. There are some good reasons for reluctance to adopt an "ethics" curriculum; among them is the opinion that teachers need all the time they can get to teach the basic aspects of science. While this is true, in some sense, it misses the point. In addition to training new scientists, at which we have done passably well (though in need of improvement), we also need to develop programs in science for non-science majors. At this we have totally failed. Despite many attempts to reach student and adult learners alike with innovative programs of

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various sorts, the public remains woefully ignorant of basic scientific concepts ((U.S.) 2010).

On the other hand, there is good evidence that when people really care about an issue, such as an environmental one near where they live, or the safety of their drinking water, or the dangers of nuclear power plants, to name just a few, non science specialists can learn the appropriate science pretty well (Avard 2006; Anonymous 2009). When science is contextualized, people remember more of it and for a longer time (Bransford et al. 2000).

At the small liberal arts college where I teach, we face some interesting obstacles to getting students in the science classroom. First, there are no requirements; nobody has to take any science at all. In fact, we suspect that one of the reasons students attend our college is just that.

Second, although most students have strong writing skills—we are known for our writing program—the innumeracy of many of them is profound. Any course that smacks of anything mathematical scares them witless.

Third, we are a very small department, with only one chemist, one biologist, one physicist, one engineer, and two mathematicians. We cannot teach any discipline to any depth—we are multidisciplinary not only by choice, but by necessity.

As a department, therefore, we have developed a number of courses in science which provide a context by including their ethical and political dimensions. (Chamany 2001, 2006; Venkataraman 2007). What follows is a brief description of three courses I teach of this nature, as examples of the concept. I then discuss some of the advantages and disadvantages of this approach, as well as some of what works and what does not. Finally, I make some concluding remarks.

The Courses

Genes and Race

I have long been interested in the intersections and connections among genes, race, and ethnicity. We have a set of very strong genetics courses in the department, taught by our molecular biologist. Partly because of this, and partly because I was interested in determining the reaction to ideas about race from a class with mixed races, I decided to combine the history, ethical questions, and the biology of the emotionally laden issue of race in human beings in a course at the introductory level (McGowan 2005).

The purpose of the course is to encourage debate, discussion, and even argument, not to present one point of view. The students start by reading a number of pieces on the history of race, including Ivan Hannaford's magisterial work "Race: The History of an Idea in the West" (Hannaford 1994, 1996; Crick 1996). From this, they learn that there is a body of scholarship that says that race was a relatively recent invention—which, by the way, does not automatically mean that it has no biological significance. We then move quickly to Ernst Mayr's "One Long Argument," (Mayr 1991) about evolution, and on from there to an introduction to genetics (Anonymous 2011a, b).

We then move to the ethical questions (Kevles 1985). No course of this kind is complete without a consideration of eugenics; the Cold Spring Harbor Laboratory site cited above has an archive of eugenics documents which are a treasure trove for students examining this issue. Garland Allen's trenchant article of some years ago, (Allen 2001) and Troy Duster's ground breaking book, (Duster 2003) are still relevant today, asking whether some current practices in genetics are eugenics in disguise.

Viewing a video about a couple who suddenly discover that they are both carriers of the Cystic Fibrosis allele, a recessive one, we discuss the ethics of their having children, given the one in four chance of having a child with the disease that will kill it in all probability before he or she is forty (the current average life span for those who survive to adulthood is 37 (Anonymous)). The wife becomes pregnant, and they learn that not only are they having twins, but both have CF. They decide to carry them to term. When the girls were a few years old they decide to get pregnant again. This fetus also has CF, and this one they abort. A third try brings them a CF-free child, who will have sisters who will die at a young age (Schwerin 1997). At each step along the way, we have a spirited discussion about the ethical issues involved.

While a very real problem in itself, this is also a surrogate for the many ethical questions that face individuals and society as a result of the advances of modern medicine.

We then turn to the controversial issues of race and medicine, race and health, race and IQ, and so forth. Is sickle anemia a "racial" disease? (It is not.) Is it ethical to disallow African-Americans from flying at high altitudes, being afraid that they are more likely to have one sickle-cell allele, which may seriously affect their ability to function in low oxygen situations? Just asking the question raises ethical hackles. Is the science good enough? How should we function when the science raises doubts, but no certainty (Stocking 1966; Braun 2002; Fish 2002; Fredrickson 2002; Duster 2003, 2005; Lee et al. 2009)?

Concluding remarks will wait until the end, but suffice it to say that the course is popular, and does bring people into the classroom who thought they would never take a science course again. And they end up if not loving the science—and some of them do love it— at least better understanding it, and a better comprehension of why it is important.

The Science and Politics of the Atom Bomb

There is not a person who was in the armed forces of the United States at the end of World War II who does not think that the atom bombs over Hiroshima and Nagasaki ended the war and therefore saved his life. Actually, however, there is quite a controversy over whether the bomb actually did cause the Japanese emperor to accept the Potsdam Proclamation, ending the war. It is this controversy which fuels the political and ethical discussion (Frank 1999; Hasegawa 2005).

First, however, must come the science. To many, the period from 1896 to 1945 was one of the most exciting periods in science, bringing about as it did a complete change in the fundamental laws of physics and our understanding of the universe.

Several books (Rhodes 1986; Hershberg 1993; Conant 2005) help the students get that excitement, as well as the enormous ethical issues contained in the development of the most powerful weapon yet devised, one that could, and did, destroy entire cities with a bomb from a single airplane. Some, in fact, refused to work on the Manhattan Project which built the bomb because they did not want the most excitement period in physics to yield the most terrible weapon then imaginable.

The ethical issues involved here have been studied and discussed for centuries, but somehow the bomb focused attention not before seen (Weart 2008). Although science and technology had long been seen as world-changers, somehow this was different. More powerful, more dangerous; hence, the stronger ethical question of should it be done. Joseph Rotblat, a Polish born scientist in the Manhattan Project, said it should not be done; he left the project, the only one to do so, when it was learned that the Germans were not working on the bomb, the possibility of a German bomb being the original, ostensible, reason for our effort. He went on to organize a statement calling for the bomb's abolishment signed by leading scientists. Saying that the bomb augured vastly new destructive powers, the statement said we have to learn to "think in a new way". "Remember your humanity," the statement stated at its end. He also organized a first meeting of Russian and American scientists in a town in Nova Scotia called Pugwash. The meetings continued, and morphed into the Pugwash Conferences on Science and World Affairs, which won the Nobel Peace Prize, along with Rotblat himself, in 1996 (Rotblat 1985; Anonymous 2011a, b).

Back to the dropping of the bomb; a case is made that Truman, newly elevated to the presidency by the death of Franklin Roosevelt in April of 1945, and his Secretary of State, James Burns, wanted to drop the bomb in order to show the world how powerful we were, and manipulated the Potsdam Proclamation in order to delay the Japanese surrender to give time to drop it (Hasegawa 2005). There was also concern that unless the bomb was dropped, Congress would be very critical of the large amount of money spent (Hershberg 1993). There is another argument, of course, which we also consider. We knew that the Japanese had moved seven additional divisions to the south of Japan, where the invasion was to take place. I ask the class if anyone could imagine not using the bomb under those conditions (we had only nine divisions crossing the Pacific for the invasion; with the additional seven, the Japanese would have ten divisions in defense) (Frank 1999). The discussion around these issues is spirited, and important.

The point is not to "decide," as a class, whether or not the bomb ended the war, but to examine the scholarship on both sides of the issue, and to raise the ethical questions which are raised by the bomb itself, and many other "advances" in technology. It has proven successful in stimulating extensive discussion on the ethics of science and technology.

Energy and Sustainability

This is a required course for the Interdisciplinary Science major, and a suggested one for the Environmental Science major. It has major sections on the physics of energy and the chemistry of energy, which introduce students to fundamental principles of energy conservation, entropy, kinetic and potential energy, as well as nuclear energy (McGowan 2011). It also attracts students from schools of design, music and drama; on questionnaires, many students say they are attracted by the study of sustainability.

The course first starts with a section on the history of the discovery of climate change, the use of energy derived from fossil fuels being one of the chief causes. Since this is not a laboratory course, using an historical approach allows us to deal with the epistemology of science—how do we know what we know and by what processes did we come to know it (Weart 2008).

Sustainability is of course as much a moral and ethical issue as a scientific one (Kates et al. 2005; Kates and Dasgupta 2007). Although the Rio Declaration of 1992 (Anonymous 1992) declares that: "Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature," the environmental justice movement developed out of a concern that all human beings were not being treated as equals in regard to sustainability issues (Bullard 1990, 1994; Hofrichter 1993; Cutter 1995; Harrington 2009). This is an ethical concern about which not enough has been written; by examining the issue at close hand, students are able to examine the complexities within which this issue is situated.

There are many such questions that arise as students examine "solutions" to the environment crisis (Fuller et al. 2009). One of the ways to reduce energy use is to increase its price; is that an equitable solution for poor people? Producing biofuels may increase the price of food; does that make sense for those who are just making it as is (Elliott 2008; Tilman et al. 2009; Willems 2009)? How can we develop a more sustainable transportation system that serves all, rich and poor (Solecki and Leichenko 2006; Schafer et al. 2009)? These questions and ones like it form the backbone of the ethical discussions.

A key part of the course is the final project, in which each student picks a country and develops an alternative energy plan for it. Students do not have to prove that their plan is the very best—they have neither the time nor skills to do that—but rather a plan that is good. Examples have been biogas in Nigeria, wind power in Toronto (some students choose to study a city instead of a country), photovoltaics for Australis, and many more. Students pay attention to equity issues, as well as technical and political feasibility, in developing their plan.

Many students have taken the course, and it gets high approval ratings. One side effect of the course, as with the others, is that a few students end up majoring in science who never thought they would.

Conclusions

As stated above, many students are attracted to the courses because of the ethical and political questions that are posed who would never otherwise take a science course. Although some are surprised by the amount of science in the courses, very few students leave the course when they find out. And some students end up concentrating in science (it is called Interdisciplinary Science) as a result of taking one or more of the courses as an experiment.

In at least one session of the Atom Bomb course, questionnaires indicated that not one of the eighteen students enrolled came into it interested in the science, as opposed to the political and ethical questions raised. Although few of these students changed their concentration to science, several did take more science courses as a result. Therefore, many more students were exposed to and learned a good deal of science; many, in fact, actually ended up liking the science part of the course as well. Obviously, this has the effect of producing a cadre of future citizens with not only a greater understanding of science, but a greater appreciation of it, and of the role it plays in society as well. This can only be of benefit to the society as a whole.

For those students who end up majoring in science—some if whom have gone on to science careers—these courses give them a context of the science they pursue as well as the ethical questions connected to it.

Countering the argument stated above that many feel there is not enough time for ethics issues, there is a strong argument to be made that students learn and retain more when their subject matter is put into an historical and ethical context. There is also evidence that students are better served by learning some issues in depth, rather than trying to "cover" large amounts of material, leaving the understanding to be very superficial (Bransford et al. 2000).

The argument that there is not enough time to "cover" a great deal of science if ethical issues are included makes no sense when it comes to non-science majors. For what do we want such future citizens to know about science? So we really want them to have a full year of a particular science, so that they can solve equations and other problems, recite the laws of motion, and so forth? Or do we want them to have a basic understanding and appreciation of science and the way it works? After all, what we really care about is what they know and remember 10 and 20 years after graduation, not what they can repeat in answer to test questions at the end of the semester. I would argue that the content of this kind of course has a much better chance of being remembered in that time frame than a traditional course, no matter how well taught.

For the science majors, the issues are different. Here, it is not a question of attracting them to science, but one of what they need to know and appreciate as working scientists. I would argue that despite the disadvantages of having to reduce the amount of science in a given course, the additional insights that are given as a result of course like this improve their own understanding of their science and its potential implications.

Back to the classic example of the atomic bomb. Before it was dropped, there was a movement to demonstrate the its effectiveness to Japanese officials, to avoid dropping the bomb on civilians. In the immediate aftermath of the bomb's success in 1945, however, the scene was different; the Manhattan scientists were elated (Feynman). It was only afterwards that ethical considerations began making themselves known, with the formation of the Federation of Atomic (now American) Scientists and the Bulletin of the Atomic Scientists. Would it have been different if the scientists therein had been made more sensitive to ethical issues? Did the bomb actually have to be dropped for the ethical issues to arise? Of course we will never know the answers to these questions, but they raise interesting possibilities.

We do know, however, that at least in one case scientists did stop their activities, voluntarily, out of ethical concerns about their science before its effects were felt. This is when molecular biologists called a halt to the research then called recombinant DNA research. Scientists were afraid that lethal pathogens resulting from their work could escape the laboratory and cause untold damage to the public. Caution was urged; controversy followed. (Cohen 1977) Research continued, after very strict guidelines for physical and biological containment.

Would this have happened had the nuclear bomb issue not sensitized scientists to the ethical implications of their work? Are there other areas where scientists need to be more aware of these issues? If so—and the answer is almost assuredly yes—would education of the kind advocated here help? Would scientists be more sensitive? Obviously, these questions are impossible to answer, but deserve being discussed in any event.

Of course the bigger question is whether or not such teaching produces better citizens, better decision making, and more humane scientists and lay citizens. There are very few data that bear on this question; and even if one could show that better and more humane decisions were made by students of such courses, which comes first? Do more ethical students take such courses, or are they made more ethical by their immersion in these issues? Anecdotal evidence tells me that it is a bit of both. There is no doubt that students with ethical concerns are drawn to such courses; on the other hand. After wrestling with the questions in class, many students indicate a decidedly increased understanding of the difficulties, and yet the importance, of taking an ethical stance in many situations.

This is an area in which much more research is necessary, and one would hope that as more attention is paid to it, the research and the funding to support it will be forthcoming. At the moment all we can say is that it certainly does not hurt, and that it very likely produces better decisions.

Ethical considerations in science are many and complex; both scientists and the lay public are well served by their explication in the classroom and elsewhere. The positive results of including ethical issues in the science classroom far outweigh the disadvantages.

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