CBE—Life Sciences Education
Vol. 12, 701–710, Winter 2013

Article

Lessons Learned from Undergraduate Students in Designing a Science-Based Course in Bioethics

John D. Loike,*† Brittany S. Rush,‡ Adam Schweber,‡ and Ruth L. Fischbach†

*Department of Physiology and Cellular Biophysics and †Center for Bioethics, Columbia University College of Physicians and Surgeons, New York, NY 10032; ‡Columbia School of General Studies, New York, NY 10032

Submitted January 29, 2013; Revised July 20, 2013; Accepted July 22, 2013
Monitoring Editor: Kenneth Raymond Miller

Columbia University offers two innovative undergraduate science-based bioethics courses for student majoring in biosciences and pre–health studies. The goals of these courses are to introduce future scientists and healthcare professionals to the ethical questions they will confront in their professional lives, thus enabling them to strategically address these bioethical dilemmas. These courses incorporate innovative pedagogical methods, case studies, and class discussions to stimulate the students to think creatively about bioethical issues emerging from new biotechnologies. At the end of each course, each student is required to submit a one-page strategy detailing how he or she would resolve a bioethical dilemma. Based on our experience in teaching these courses and on a qualitative analysis of the students' reflections, we offer recommendations for creating an undergraduate science-based course in bioethics. General recommendations include: 1) integrating the science of emerging biotechnologies, their ethical ramifications, and contemporary bioethical theories into interactive class sessions; 2) structuring discussion-based classes to stimulate students to consider the impact of their moral intuitions when grappling with bioethical issues; and 3) using specific actual and futuristic case studies to highlight bioethical issues and to help develop creative problem-solving skills. Such a course sparks students' interests in both science and ethics and helps them analyze bioethical challenges arising from emerging biotechnologies.

INTRODUCTION

Over the past 40 yr, bioethics has been emerging as an important, as well as popular, subject in both the academic and public sectors. Yet, education in bioethics remains far from established in undergraduate bioscience curricula. As a result, undergraduate students are generally unaware of the many historic and current ethical dilemmas that have been generated by advances in science.

The college setting provides an excellent environment for introducing young scientists and future healthcare professionals to the ethical conundrums they will undoubtedly confront in graduate schools and their professional careers. Just as learning the language of science involves years of education, becoming familiar with the language and principles of bioethics and developing ethical reasoning skills demand time from students. Indeed, for science and medicine to advance responsibly, science and ethical reasoning must progress in tandem.

In this paper, we first present ways in which science and ethics can be integrated into an introductory undergraduate course in bioethics. We then use our experiences from teaching two such courses in bioethics at Columbia University (offered each Spring semester from 2008 to 2012) as a model for how to achieve this goal. In addition, we analyze students' bioethical strategies (defined as *ethical decision-making criteria)* as representative of their reflections, attitudes, and analytical interpretations in reconciling the bioethical challenges emerging from new biotechnologies. Based on our experiences teaching these courses and students' strategies, this study presents recommendations in order to provide educators and institutions with valuable insights into structuring a multidisciplinary course in bioethics.

DOI: 10.1187/cbe.13-01-0012
Address correspondence to: John D. Loike (jdl5@columbia.edu).

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Integration of Science and Ethics at the Undergraduate Level

The objective of integrating science and ethics in an educational setting is to enable science and pre–health students to begin to develop the critical-thinking skills and knowledge required to identify and address bioethical challenges intrinsic to their chosen professions. The conceptually complex nature of emerging biotechnologies and, subsequently, their bioethical challenges require a multidisciplinary educational platform in order to build an understanding of the broader context of scientific and medical endeavors. This involves considering scientific, legal, social, philosophical, historical, and ethical perspectives in analysis (Adam *et al.*, 2011). It is advantageous, as well as socially responsible, for students interested in careers in science and healthcare to fully comprehend and assess the underlying scientific research and be able to identify the basic ethical principles for addressing bioethical dilemmas prompted by emerging biotechnologies.

While there are a variety of pedagogical platforms in teaching bioethics, the courses offered at Columbia University are predicated upon the concepts that good bioethics begins with good science and good science requires good ethics. Our two Columbia University courses attempt to integrate science and ethics in a meaningful way through a variety of in-class activities and assignments (Northwest Association for Biomedical Research, 2012). This science-based approach is not just logical; it engages science students with the ethical aspects inherent to their disciplines. Additionally, it may also lessen a concern of some students who regard bioethics as an imprecise subject and not intellectually challenging enough to be included in undergraduate science education (Pearce, 2009).

In the United States, most undergraduate institutions do not formally require an ethics course to obtain a degree in the biosciences (Zaikowski and Garrett, 2004). In the United Kingdom, however, the Quality Assurance Agency for Higher Education (QAA) introduced expectations for higher education in the biosciences, "Benchmarking Subject Standards for Bioscience," that included "challenging social, ethical and legal problems." The primary objective of incorporating these topics into the curricula is to enable students "to construct reasoned arguments to support their position on the ethical and social impact of advances in the biosciences" (QAA, 2007). Several educational professionals predict that, at this point in the United States, an increase in bioethics education is inevitable, due to the confluence of a number of factors. These factors include scrutiny and regulation due to increased public awareness of the impact of basic research on society, increased public and private funding, increased diversity and collaboration among researchers, the impressive success and speed of research advances, and high-profile cases of misconduct" (Eisen and Berry, 2002, p. 38).

Crossroads in Bioethics and Ethics for Biomedical Engineers

In 1997, *Nature* reported the use of somatic cell nuclear transfer to clone Dolly, the sheep (Wilmut *et al.*, 1997). Shortly thereafter, *Science* reported methods to culture and maintain human pluripotent stem cells (Thomson *et al.*, 1998). Both articles marked a monumental time in science and bioethics. In the aftermath of these reports, bioethical issues became an increasingly popular topic in the academic and public press. The plethora of political, public, and academic bioethical debates on cloning and stem cells, for example, underscores the need for undergraduates studying science to be cognizant of such topics and to be prepared for future bioethical challenges emerging from evolving biotechnologies. Ultimately, young scientists need to develop the tools to communicate about and contribute to the resolution of current and future bioethical dilemmas.

For these reasons, a group of scientists and bioethicists at Columbia University set out to incorporate ethics into the bioscience curricula. In 2003, Crossroads in Bioethics was offered by Columbia College to any student majoring in biology or premedical science. In 2007, Ethics for Biomedical Engineers, a required course for all senior undergraduate students majoring in biomedical engineering at Columbia University's Fu Foundation School of Engineering and Applied Sciences, adopted an educational format similar to Crossroads in Bioethics. The overall objectives of these two courses are to introduce future scientists and healthcare professionals to the ethical questions they will confront in their professional lives, to enable them to develop strategies to address bioethical dilemmas, and to help students learn how to present their views on how to manage and resolve contentious bioethical issues. Both courses are taught and directed by one of the authors (J.D.L.).

Crossroads in Bioethics is an elective science course (15 lectures with 75 min per lecture) for second-, third-, and fourth-year biological sciences majors. This course counts as a science credit toward fulfillment of the biological sciences major requirements at Columbia University. Crossroads in Bioethics focuses on, but is not limited to, examining current and future bioethical issues emerging from biotechnologies. Examples of such biotechnologies include reproductive and therapeutic cloning, stem cell technology, and reproductive biology. In addition, some topics presented are more medically related, such as the ethical challenges of alternative medicine (e.g., homeopathy) and recruiting egg donors from college students (see Table 1).

Ethics for Biomedical Engineers is a degree requirement for all fourth-year biomedical engineering majors at Columbia University's Fu Foundation School of Engineering and Applied Sciences. It is worth the same number of science credits as Crossroads in Bioethics (i.e., 2 credits), and includes the same amount of class time (i.e., 15 lectures with 75 min per lecture). Ethics for Biomedical Engineers focuses on topics similar to those covered in Crossroads in Bioethics. Because students in this course are studying to become biomedical engineers, a few topics, such as the ethical challenges of brain imaging and nanotechnology, are included in the curriculum (Table 1).

Introduction to Bioethical Theories

Chief aims of these courses are to help students identify bioethical dilemmas and formulate their own bioethical decision-making strategies; from the first lecture onward, they are encouraged to think creatively about proposing practical resolutions to bioethical dilemmas. The course material and style of presentation is likewise designed to make students aware that bioethical analysis is not bound to existing theories and principles that may conflict with one or trump

Table 1. Topics for Ethics for Biomedical Engineers and Crossroads in Bioethics[a]

Stem cell technology
Patenting genes[b]
Human trafficking
Organ trafficking
The science and ethics of human cloning
Reproductive medicine: IVF, genetic screening, recruiting egg donors, and preimplantation genetics
Medical tourism
Participation of physicians in executions using lethal injections
The science of romance and behavioral genetics
Alternative medicine
Ethics of disaster medicine
Human–animal chimeras
Global bioethics: respecting culture and religion
Cell phones, electromagnetic radiation, and their ethical consequences[b]
Informed consent for the uneducated
Bioterrorism
Nanotechnology[b]
Brain imaging technologies[b]
Regulating biomedical research

[a]This list represents topics taught over the years in both courses; not all topics are taught each year in each course.
[b]Topics offered only in Ethics for Biomedical Engineers.

another (McMahon, 2011). It is crucial that a course in emerging biotechnologies both alerts students to a multitude of real-life issues and helps them develop critical-thinking skills to evaluate such dilemmas in situations in which established approaches may not be applicable.

The first lecture of these courses, entitled "Introduction to Basic Bioethics," includes, but is not limited to, reviewing theories in contemporary bioethics and natural law focusing on principlism, which describes the four major bioethical principles of autonomy, beneficence, nonmaleficence, and justice (Department of Health, Education, and Welfare, 1979; Beauchamp, 2007; Beauchamp and Childress, 2001, 2009). These principles are highlighted throughout the course by analyzing how to apply these principles to actual cases. Autonomy, for example, was discussed regarding the increasing global opportunities of medical tourism and gender selection.

Readings and Assignments

Each week, the readings and assignments are designed to introduce students to an emerging biotechnology and its ethical considerations. Reading assignments include primary science and technology papers published in peer-reviewed journals and relevant bioethics papers from bioethics journals. To expose students to a variety of arguments, the course instructor chooses bioethics papers that present several opposing viewpoints on a topic. Each week, the course instructor poses a question based on the assigned readings and students post their responses via an online portal at least 2 d prior to class. These weekly assignments ensure that students have carefully read the assigned material and are prepared to engage in informed in-class discussions. Sample thought questions include: "Should the U.S. Patent Office allow the patenting of genes?" and "Under what circumstances might gender selection be ethical?" For some lectures, more speculative thought questions were posed: "Is it ethical to clone a Neanderthal person?" and "Will brain imaging be a valid test for lie-detection in court?" The course director uses the students' responses to gauge students' gaps in knowledge and plan discussions accordingly. One technique to accomplish the integration of science and ethics is exemplified in their final exam paper (Table 2).

Students have the opportunity to apply what they learn in the course to a specific case of their choosing. In preparing their final exams, students work in pairs in an effort to emphasize that collaboration in scientific research provides diversity of thought, stimulates creativity, and enhances critical-thinking and problem-solving skills (Loes et al., 2012). Students select a recent primary science article from a top-tier journal that describes a new biotechnology and then they must review the technology and present the bioethical dilemma that it elicits. In discussing these topics, students are challenged to evaluate the following: Why is the technology innovative, and how well do the data support the results? What new bioethical dilemmas emerge from the technology? How would you resolve the new bioethical dilemmas raised, and what factors should be considered in order to identify possible resolutions? By this method, students learn how to identify timely bioethical concerns from reading primary scientific papers while simultaneously learning the relevant science. These assignments mark the first step in developing critical-thinking skills necessary for ultimately identifying ethical dilemmas and formulating workable resolutions.

METHODS

To assess these courses, we analyzed student responses to the required take-home, nongraded prompt:

> The last assignment of the semester is to describe your own formulated strategy to address a bioethical dilemma. What will be your strategy to resolve bioethical dilemmas? One page limit.

Using the methods of Hsieh and Shannon (2005), the qualitative data analysis for this study was based on the conventional guidelines for content analysis. The process began

Table 2. Assignment frequency and portion of final grade

Weekly	Write a one-page response to a thought question about bioethical concerns emerging from a new biotechnology.	10%
Semester	Attend a minimum of two bioethics or scientific seminars at Columbia University and write a one-page review of an innovative thought or idea obtained from the seminar.	Not graded
Semester	Midterm: write a 1000-word op-ed piece in the appropriate format for submission to the *New York Times*. Content should reflect an original thought on a contemporary bioethical issue and include a brief explanation of the underlying science that is accessible to a lay audience.	30%
Semester	Final exam paper: write a three- to five-page paper analyzing the bioethical ramifications of a scientific biotechnology paper published within the past 6 mo and discuss specific approaches on how to resolve said bioethical dilemmas.	30%
Semester	Write a one-page summary of personal ethics decision-making strategy to resolve bioethical challenges.	Not graded
Semester	Class participation: contribution to debates, role-playing, and discussions, including class attendance.	30%

with an initial reading of a subset of 80 student strategies to gain a sense of the whole and to begin to identify the topic area, which formed the initial coding scheme. Coded-response themes were taken directly from the texts and categorized into meaningful clusters (topic areas) and then into a broader organizational scheme: factors to consider in developing bioethical strategies, theories, principles, and outcomes. All of the student strategies were read a minimum of three times (by J.D.L. and B.S.R.) in order to develop the codebook further; this included verifying concepts and modifying the coded-response themes and topic areas. Each step of the codebook creation was discussed and agreed upon by both authors (J.D.L. and B.S.R.). To distance the final analysis from the personal classroom experience of the course director, B.S.R. conducted the final coding and A.B.S. conducted the statistical analysis. Neither partook in the design or teaching of either course and held no expectations or preconceptions of what the student strategies should ideally encompass (Corbin and Strauss, 2008). Topic areas were recorded as either present or not present for each individual response, rather than by frequency of topics recorded per response. Topic areas present in fewer than 10 responses total were considered too minor to be included in the results tables.

In the academic years 2008 and 2009, weekly classroom sessions for both Crossroads in Bioethics and Ethics for Biomedical Engineers consisted of ∼25% class discussion and debate and 75% lecture (a combination of guest lecturers and director lectures). Student course evaluations in 2009 reflected a desire for more class time to be devoted to group discussion and debate. The two courses were modified accordingly. In the academic years 2011 and 2012, the courses were redesigned to consist of ∼75% class time devoted to discussion and debate and 25% of the time devoted to lecture. To test for any differences in student outcomes due to this change in class structure, we grouped and analyzed responses from years 2008 and 2009 and years 2011 and 2012 separately as "cohort 1" and "cohort 2," respectively.

Statistical Analysis

Differences in the topic area frequencies of two study groups (cohort 1 and cohort 2) were evaluated using either Yates's continuity-corrected χ^2 test or Fisher's exact test. (Fisher's exact test was applied if the number of expected responses per cell was fewer than five. Due to the relatively small sample sizes, the Yates's χ^2 test was applied, rather than Pearson's χ^2 test.) All reported P values are two-sided, and P values < 0.05 are regarded as statistically significant. The same tests were used to evaluate differences in male and female strategies overall. Statistical tests were performed with the SAS software package, version 9.2 (SAS Institute, Cary, NC).

Benefits of a Qualitative Approach

We chose to conduct a qualitative research study for a number of reasons. First, an objective of this study was to gain an empirical understanding of how undergraduate science students internalize an introductory course in bioethics rather than to merely test a hypothesis. As such, the open-ended prompt to describe bioethical strategies encouraged students to express themselves in ways that quantitative surveys cannot. To our knowledge, no comparable study of this kind has been reported as of June 2013. Second, all students' voices are equally represented (i.e., the one-page response) as opposed to the classroom setting, in which student participation is variable.

Methodological Limitations

Measures were taken to deter students from tailoring their strategies to conform to the views of the course director (J.D.L.). First, the only viewpoint conveyed by the director to the students was that the objective of this course was to enable students to identify dilemmas and then to develop their own bioethical strategies. Second, students were informed that their responses would not be graded. Third, students were asked to write their responses outside the classroom in order to distance the director from serving as "interviewer" (Denzin and Lincoln, 2005). Finally, students were asked to submit their responses via email to both the director and to the teacher's assistant in two formats: one without any authorship and the other including the name of the author. All responses were read without their authorship being known.

RESULTS AND DISCUSSION

Factors to Consider in Developing a Bioethical Strategy

Students listed a variety of considerations or factors in developing a bioethical strategy (Figure 1 and Table 3).

Table 3. Factors students considered in developing bioethical strategies[a]

	Coded-response themes
One or more bioethical principles	Autonomy, beneficence, nonmaleficence, and justice
Need for interdisciplinary approach	Inclusion of diverse backgrounds, disciplines, and values; understand different sides of argument and points of views; act as devil's advocate
Social factors	Taking the current social/cultural environmental/religious context into account
Science and technology	Understanding the relevant science and technology
Moral intuition	Biases, intuition, moral/ethical compass, impulse, and gut instincts—how these factor into decision-making
No right or wrong	Gray areas, no right or wrong answers to all/some bioethical dilemmas
Multiple strategies	Multiple/many strategies or no single strategy; no set of rules; no standardization that can be applied to all bioethical issues
Utilitarian framework	Utilitarianism: benefit most, harm least; greatest good for the greatest number of people
Technological innovation as means of resolving bioethical dilemmas	Technological/scientific innovation can sometimes solve ethical dilemmas

[a]One student's response was eliminated from the analysis because it did not follow the prompt (it consisted entirely of a personal anecdote).

The most prevalent included: citing at least one bioethical principle (Beauchamp and Childress, 2001), the need for an interdisciplinary approach, and social responsibility. An interdisciplinary approach considers scientific, legal, psychological, and social aspects of a bioethical conundrum. Social aspects of a bioethical challenge involve relevant social, cultural, environmental, and religious considerations. Other common considerations cited were the understanding of the science and technology being deliberated, historical precedents, and the fact that there are often no clear right or wrong answers in bioethics. More than 50% of the students stated that developing bioethical strategies required an interdisciplinary approach. In contrast, less than 15% of the students, cited the use of a utilitarian approach to address a bioethical issue. In addition, less than 10% of the students recommended the use of technological innovation as a means to resolve bioethical dilemmas. There were no statistical differences between students' responses to identifying strategic factors with respect to gender responses or between cohort 1 and cohort 2 (unpublished data).

Thirty-four percent of students wrote about the role of their gut instincts, moral compasses, intuitions, or impulses in processing bioethical dilemmas (grouped together as "moral intuition"). This is roughly equal to the number of students (35%) who wrote about the importance of understanding the science and technology behind the emerging biotechnologies in question. This finding is quite significant, as the role of moral intuitions in deliberating bioethical issues has never been a part of any structured lesson plan nor does the course director (J.D.L.) recall moral intuition being a prevalent theme in any class discussions. Moral intuition was tangentially discussed only in the lecture topic dealing with creating animal–human chimeras[1] that possessed human brain cells or human reproductive organs.

[1]A human–animal chimera is used in these courses to illustrate an organism in which human stem cells are transplanted into specific locations of a fetus of a mouse or cow to attempt to reconstitute specific human tissues or organs, such as a uterus, sperm, eggs, or brain neurons.

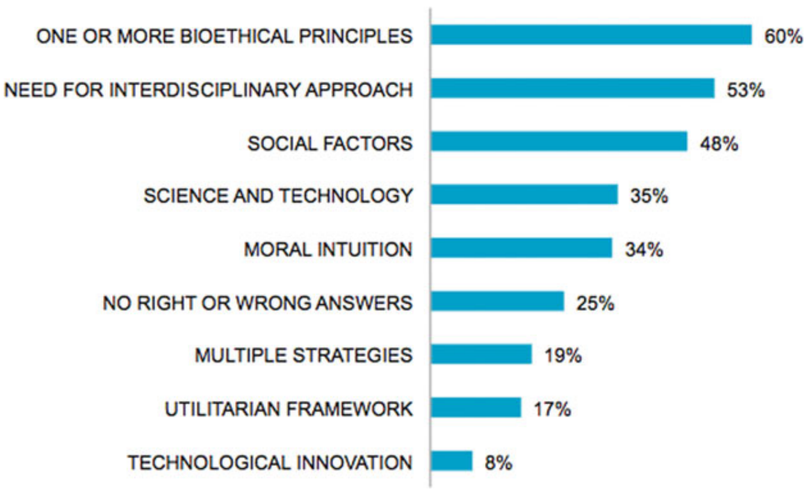

Figure 1. The factors that students ($n = 139$) identified in developing strategies to resolve bioethical challenges. See Table 3 for a list of all key words and phrases from student responses (coded-response themes).

The language the students used to highlight the importance of moral intuition is revealing of how students internalize an introduction to bioethics:

> "With newer technologies and scientific advancement, this is inevitable—it is difficult, at times, to foresee the effects of our discoveries and inventions on medicine, health and society. I therefore strongly believe that 'gut feeling,' although unreliable, should be given fair weight in our strategies to deal with bioethical issues."—Male, 2011

> "I can rely on my preexisting sense of intuition to be my moral compass."—Male, 2011

> "My gut reaction's very limited application is to let me know whether or not I'd personally use whatever biotechnology has been presented. In order to decide about access and application for society in general, it takes thought with a bit more equanimity."—Female, 2009

> "This first step that I take when approaching a new bioethical dilemma takes place almost as soon as I hear about the problem or understand the situation. This is an awareness and acknowledgement of my immediate 'visceral reaction' or 'gut feeling' that develops."—Male, 2011

> "I would consider previous ethical decisions that have been made in this field. I think it is then very important to consider how, if at all, my personal feelings, biases, or self-interest might affect my ethical judgment and reasoning."—Female, 2011

Students from other undergraduate institutions have also expressed similar perspectives on moral intuition in other bioethics-based settings (Rest *et al.*, 1986; Turrens, 2005; Lysaght *et al.*, 2006; Pearce, 2009; Sadler, 2010). Lysaght and colleagues, for example, found "attitudes toward morally controversial issues, such as animal experimentation, genetically modified foods, and embryonic stem cell research, were seen as being determined more by one's own 'internal' set of moral values that are learnt from an early stage of development than from externally developed codes of ethics" (Lysaght *et al.*, 2006). Concepts of moral intuitions were introduced in the course Social Impacts of Biology at Newcastle University in the United Kingdom. During class sessions, students were asked explicitly to share their "gut reactions" as part of a structured small-group discussion strategy based on the pedagogical methods described by De Bono in *Six Thinking Hats* (De Bono, 1999).

Debates contemplating the role of moral intuition in ethical reasoning have existed since the times of Plato and Aristotle and continue to persist in contemporary fields of cognitive science and moral psychology (Haidt, 2001; Singer, 2005; Sinnott-Armstrong, 2008a,b). Recent technological-based studies have used functional magnetic resonance imaging, as well as other forms of neuroimaging, to attempt to understand the physiological basis of moral instinct. These studies appear to have identified specific sites within the human brain that seem to be involved in ethical reasoning and moral judgments (Greene *et al.*, 2001; Greene and Haidt, 2002).

There is a clear need to facilitate students' cognizance and informed reflection on the impact of moral intuitions on ethical reasoning, as is evidenced by the prevalence of moral intuition in student responses, in contrast to the lack of such reasoning during in-class discussions. In future Columbia University bioethics courses, specific case studies will be introduced to stimulate students to examine and discuss the role of moral intuition in formulating bioethical decisions. One example of such a case study relates to the futuristic utilization of a cow that possesses a human uterus. Recent technological innovation has made it theoretically possible to implant human stem cells into a cow embryo to create a human–cow chimera that will form a functional human uterus (Loike, 2013). Addressing moral intuitions in class via role-play scenarios allows students to elicit their "gut feelings" and enables them to consider the interplay of moral intuitions with traditional ethical theories.

Interestingly, 25% of the students expressed their opinion that there are no right answers to resolve bioethical dilemmas and that many of these issues fall into the gray zone, as reflected by the following representative students' comments:

> "I believe there is no definitive stance to any issue, because if there was certainty in any of them, then it wouldn't be an issue. I also was persuaded by other students at times to certain points of view, but again everything is relative, since it depends on whether one is the benefactor or not."—Female, 2008

> "What I've come to realize over time through the class discussions, involving various bioethical issues that have arisen in the past and have been resolved or of contemporary issues that are still being debated, is that in dealing with bioethics one shouldn't always enter a discussion seeking to determine a 'right' versus a 'wrong.' Oftentimes, such a clearly defined distinction does not exist. In fact, it seems that most bioethical debates revolve around issues that are precisely without a clear right or wrong."—Male, 2009

> "Ultimately, there is not one 'right' solution to any bioethical issue and there is inevitably always a grey area of what is ethical, in which situation, and for which reason. I think the first step in dealing with these issues is recognizing the fact that they are in fact complex issues which require in depth research and development to reach the best solution."—Female, 2012

Though many issues in bioethics may never reach a consensus agreement, the objective is nonetheless to always strive for the best possible resolution. The idea of developing a position with strong evidence resonates with a scientific mind-set. While there may not be a clear right or wrong resolution, there are solutions that may be more strongly justified than others. This is why students are pushed to identify a possible resolution in their final paper and in their reflections on developing their bioethical strategies. Moreover, the failure to reach a consensus may reflect the fact that the topics discussed in these courses are often futuristic (e.g., human cloning, generating human–animal chimeras, new technologies in reproductive medicine).

Bioethical Principles

Beauchamp and Childress's four guiding bioethical principles (Beauchamp, 2007; Beauchamp and Childress, 2001) are the most-quoted principles by students (Figure 1). This result is not surprising, as the first lecture of these two courses discusses how these dominant principles have guided research with human subjects since the commissioning of the Belmont Report in 1978–1979 (Department of Health,

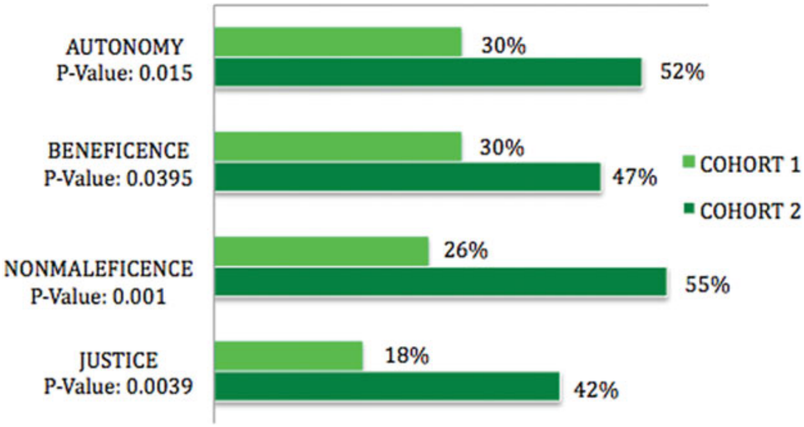

Figure 2. Bioethical principles cited in student responses and significant differences between students who had various proportions of class time for discussion. Cohort 2 ($n = 62$), years 2011 and 2012, with 75% class time devoted to discussion articulated all four bioethical principles at greater frequency than cohort 1 ($n = 77$), years 2008 and 2009, with only 25% class time devoted to discussion.

Education, and Welfare, 1979). In fact, the U.S. Presidential Commission on Bioethics (www.bioethics.gov) relies heavily on these principles. Interestingly, students who completed the courses in the years with more class time devoted to discussion, debate, and role-playing (cohort 2) cited Beauchamp and Childress's principles at a greater frequency than those in years with less class time devoted to discussion (cohort 1). It should also be noted that students did not mention ethical theories, such as consequentialism and deontology, at significant frequencies in their responses (Figure 2).

Students' Reflections on Incorporating Bioethics into the Science Curriculum

A handful of students (13%) also wrote about how their newly acquired knowledge of bioethics would make them more ethical and/or cognizant professionals (scientists and/or physicians). Some students focused on the task at hand (to formulate a strategy) more strictly; however, many responses intertwined commentary on their personal growth as a result of, and/or in reaction to, taking these courses. This is particularly significant because this sort of reflection was not asked of them in the prompt. The fact that students cited this reflection in their "strategies" is a telling indication of the powerful impression made by exploring the bioethical implications of emerging biotechnologies. In future courses, it will be helpful to give students a second prompt, so they have the opportunity to reflect on their personal growth and reactions to the course.

There are only a few published undergraduate university bioethics courses that include topics on professionalism. At the University of South Alabama, Mobile, for example, students who completed Issues in Biomedical Sciences were surveyed specifically on professionalism in science: 68.9% agreed that they were "less likely to indulge in unethical behavior as a result of this course," 82.4% agreed that the "material presented in this course has helped me prepare for a professional career," and 81.1% agreed that "my approach to thinking and dealing with ethical issues has changed as a result of this course" (Turrens, 2005). It is reasonable to speculate that more students in Ethics for Biomedical Engineers and Crossroads in Bioethics shared these sentiments than the number who wrote about them unprompted in their strategies:

> "It has been a challenging and eye opening experience to discuss with my peers and mentors the exciting new developments on the forefront of biology and medicine and the ethical dilemmas that often come along with them."—Male, 2011

> "We were asked on many occasions to form concrete opinions about ethical decisions that we had been made generally aware of, but had not actually given the proper time to. Some of these questions were easy for me to answer, and some a little harder. Many appeared straightforward on the surface but quickly became convoluted as more facts were brought to the surface. I want to discuss some of those that came up that I really had to think about, or some that took some interesting turns as these are the ones that really shaped my experience."—Male, 2012

> "This class has shown me that the philosophical side of science is just as important as the science itself. Going into medicine, I will probably be making decisions every day that will directly affect another life. I hope to use the process of thinking that I learned in this class to not make the right decision—because I also learned that right is a very relative word—but to make decisions that I think will best benefit the patient and that I will not regret down the road."—Male, 2009

> "I think that this class has definitely helped me prepare for the upcoming years in medical school and many more years in medicine. Many topics we discussed in class or through weekly assignments were things that I never considered seriously beforehand and I learned that I myself have a lot more to learn."—Female, 2009

> "As a new Biomedical Engineer, I appreciate the Bioethical course that I am taking. It gives me a wider perspective towards other culture's opinion about science and increase [*sic*] consciousness with current issues."—Female, 2011

Landscape of Bioethics Undergraduate Education

In 1976, during the very early years of the interdisciplinary field of bioethics, the Hastings Center (1976) published a report entitled *The Teaching of Bioethics: Report of the Commission on the Teaching of Bioethics*. This report discussed bioethics education at every level—from elementary school education to master's and PhD programs. The report states that expertise in multiple disciplines and the inclusion of various specialists outside the academic community are necessary for teaching bioethics. The report also recommends the use of other types of ethical theories to resolve each case or issue discussed in the course, allowing students to begin to gain theoretical competence and to prevent indoctrination by the teacher. Finally, the goals of any course in bioethics should foster problem-solving skills, with special attention given to "questions of normative theory" or what ought to be according to certain moral standards (Hastings Center, 1976, p. 6). In 2012, while reviewing the pedagogical design of Crossroads in Bioethics and Ethics for Biomedical Engineers, we identified common teaching methodologies with the recommendations of the Commission on the Teaching of Bioethics.

Theoretically, undergraduate universities could offer bioethics as a stand-alone course or as a series of topics integrated into a science course (Kramer *et al.*, 2009; McGowan, 2013). There are many advantages to incorporating bioethics into science classes. Students, for example, are educated how to make direct connections between what is being learned in the classroom with the bioethical challenges that are being presented in the public press and in professional journals. Students also learn more about models of social responsibility for scientists (Chamany *et al.*, 2008). Science professors, however, express that the lack of time is the greatest barrier to incorporating ethics into a science class (Booth and Garrett, 2004; Downie and Clarkeburn, 2005).

The following are two examples of introducing topics in bioethics into a science course: At Mount Holyoke College in Massachusetts, science majors in the upper classes performed a 50-min mock debate on cloning and stem cells for the underclassmen in an introductory biology course modeled after the President's Council on Bioethics (Fink, 2002). The goals for the mock debate were that "the students who participated will read the newspapers more often, will share their opinions on such important matters, and will think more carefully about the intersections between scientific information and societal policy" (Fink, 2002, p. 137). At the University of Glasgow in Scotland, 6 h of various honors biology courses is reserved for highly structured, dilemma-based, small-group discussions (Clarkeburn *et al.*, 2000). The goal of these discussions is to support the development of students' "ethical sensitivity" or their ability to perceive, understand, and analyze ethical elements in any situation (Clarkeburn *et al.*, 2000).

Based on the time allotted to bioethics in these science courses, one might speculate that 50 min or 6 h of bioethics per semester is hardly adequate to achieve any educational goals beyond bringing students' attention to topics of which they might not be aware. In addition there is inadequate time to spark enough interest in bioethics that would inspire students to pursue more bioethics education in the future. In fact, students at Mount Holyoke College expressed frustrations about not having enough time to ask questions and about the lack of follow-up discussion (Fink, 2002). While introducing bioethics is stimulating, it is doubtful that passively watching a mock debate would spur the development of the skills needed to enable students to think more carefully about science and society on their own. Furthermore, students may not be able to grasp the depth of certain bioethical dilemmas without adequate awareness of ethical reasoning or a more detailed understanding of the underlying science within a theoretical, actual, and translational perspective. Similarly, at the University of Glasgow, "it was apparent that most students were very unfamiliar with ethical appreciation of scientific topics. They also could not, when prompted, describe their ethical decision-making methods" (Clarkeburn *et al.*, 2000, p. 70). While both of these projects successfully introduced a large number of young scientists to the field of bioethics by using innovative teaching methods, they did not equip students with their own analytical tools to resolve or even discuss bioethical dilemmas.

There are only a few accounts of undergraduate level bioethics courses that equip students with the tools to deliberate bioethics dilemmas on their own. In the following two examples, each course is taught by a research scientist/bioethicist, and each includes some elements of ethical theory and problem solving in their respective courses. All undergraduates in the Biomedical Sciences Program at the University of South Alabama, Mobile, are required to take a course called Issues in Biomedical Sciences (Turrens, 2005). The aim of this course is "to expose students to current bioethical issues and raise their awareness concerning responsible conduct of research" (Turrens, 2005, p. 330). The professor of this course found, through both the informal process of open discussions and also students' evaluations of various bioethical questions, that the course indeed helped students become aware of current problems and taught them to analyze controversial issues.

At Newcastle University in the United Kingdom, all applied biology, biology, and zoology majors are required to take Social Impacts of Biology. The foremost goal of the course is to educate students to analyze and reason about bioethical issues (Pearce, 2009). At the end of the course, students take an examination to test their ability to write a clearly argued case. Students must prove that they can develop a logical, structured approach to a specific problem or to a general type of problem. Many students gave enthusiastic reports about the opportunity that Social Impacts of Biology gave them to exercise their thinking abilities. Though these two courses are more in line with the objectives of the Commission on the Teaching of Bioethics and QAA recommendations than the previous two examples, they still do not emphasize the need to comprehend the scientific background of the topic. Likewise, a criticism of offering a separate course in bioethics is that separating bioethics from the science courses promotes a dissociation of the ethical issues from the basic biology being discussed (Downie and Clarkeburn, 2005).

General Recommendations

As undergraduate science students are, by and large, beginners in the process of bioethical analysis, they are likely to benefit from structured class discussion specifically designed to facilitate the application of ethical theories and principles in order to improve their ability to strategize. In the classroom, students should be encouraged to be active participants in debates, panel discussions, or role-play scenarios.[2]

[2]On the topic of stem cells, for example, one student was asked to defend the Catholic Church's position that personhood begins at conception, while another student had to defend the position that personhood begins during embryological development, and a third student had to defend the position that personhood begins at birth.

Explicitly asking students to apply ethical theories and principles to topics and case studies throughout the course enables students to learn by practice and to begin to recognize the strengths and shortcomings of these various modes of ethical reasoning. Our finding that students who had more in-class discussion time were better able to articulate and apply the major principles (Figure 2) indicates that we are on the road to achieving this educational objective.

CONCLUSIONS

Based on our experience and the literature, we provide the following recommendations for designing an integrated science-based course in bioethics for undergraduate scientists:

1. Include ethical topics that arise from emerging biotechnologies.
2. Begin each topic by reviewing the scientific basis of the biotechnology.
3. Structure the class as a seminar-style course that involves a great deal of instructor- or student-led discussion.
4. Include a dialogue on the impact of moral intuitions.
5. Use current and futuristic case studies to highlight bioethical issues and to foster creative problem-solving skills.
6. Encourage students to begin to formulate their own strategies.
7. Recruit faculty members with expertise in bioethics and/or biotechnology as codirectors. This can be an enriching educational experience and ought to be a welcome addition to such an interdisciplinary course.

Presenting bioethics early in science education reinforces young scientists' sense of the importance of ethical reflection in their future careers and gives students some confidence in thinking about how to resolve bioethical conundrums they are likely to confront. The kind of critical-thinking and communication skills introduced in Crossroads in Bioethics and Ethics for Biomedical Engineers form the foundation necessary for future scientists and healthcare professionals to one day effectively educate and communicate well-informed views concerning bioethical challenges to the public.

In summary, the dynamic nature of the rapidly evolving biotechnologies and subsequent medical applications must be associated with a great social responsibility for all involved. As science educators, it is our duty to introduce the next generation of scientists and healthcare professionals to practical ways of actively engaging with the confluence of science and the broader context of healthcare. Such science-based courses in bioethics spark students' interest in both science and bioethics.

For the topic of "cloning a Neanderthal person," students were asked to act out different roles. One student took on the role of the scientist who cloned the Neanderthal. Another student was the bioethicist who was opposed to cloning, and a third student acted as the cloned Neanderthal. For other topics, students were asked to serve on a panel and discuss the scientific, ethical, and cultural positions of a specific topic, such as the ethics of compensating an egg donor. In another educational discussion platform, two students had to present to the class a controversial research project, such as reconstituting a human brain into a mouse. The class acted as an animal care committee to deliberate whether or not to approve or reject the proposal. Using these varied pedagogical approaches stimulated interest in the discussion among all the members of the class.

ACKNOWLEDGMENTS

The authors thank Dr. Deborah B. Mowshowitz, Chair of the Undergraduate Committee and Director of Undergraduate Programs and Laboratories, Department of Biology at Columbia College; Dr. Andrew Laine, Department Chair and Professor of Biomedical Engineering and of Radiology (Health Sciences); and the Department of Biomedical Engineering for the opportunity to teach these courses. We acknowledge Jennifer E. Miller, Edmond J. Safra Center for Ethics, Harvard University, for her thoughtful comments, and my students (Ayelet Evrony, Lena Bell, Alyssa Scheiner, and Helena Wu) who helped edit this article. In addition, we thank all the superb students who have made these educational courses challenging and successful.

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