
AC 2012-3061: USE OF CASE STUDIES AND A SYSTEMATIC ANALYSIS TOOL TO ENGAGE UNDERGRADUATE BIOENGINEERING STUDENTS IN ETHICS EDUCATION

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Use of Case Studies and a Systematic Analysis Tool to Engage Undergraduate Bioengineering Students in Ethics Education

Abstract

In addition to developing technical skills, engineering undergraduates must also be prepared to navigate the ethical issues they will encounter during their professional careers. In bioengineering in particular, students must be prepared to identify and solve the wide variety of ethics problems encountered in this rapidly-progressing field. Because of the importance of ethics education in engineering, ABET criteria for accreditation includes the requirement that graduating students be equipped with an understanding of professional and ethical responsibility and the ability to engage in engineering design while considering ethical, economic, environmental, social, and safety constraints. At the University of Washington, this requirement is satisfied by addressing ethical responsibility and engineering ethics problems throughout the bioengineering curriculum. Students are first exposed to ethical issues in the context of bioengineering in a recently-implemented course entitled Introduction to Bioengineering Problem Solving, BIOEN 215. This course serves as the foundation for the later bioengineering courses which also involve ethics instruction, including junior-level core courses and the Capstone Senior Design sequence.

In this paper, we present our approach to engaging students in bioethics, through the use of case studies and a systematic tool that can be used to solve any type of ethics problem. During the initial two offerings of BIOEN 215 in 2011, case studies were utilized to introduce students to the wide range of possible ethics problems in bioengineering and to illustrate the complexity of ethical challenges. Students were introduced to case studies involving human subjects, medical device risk, research misconduct, and clinical trials in developing countries. Established medical research guidelines, ethical theories, and professional codes of ethics were discussed in the context of case studies. Case studies encompassed situations faced by clinicians, medical researchers, undergraduates, etc. and were presented to students and subsequently analyzed in groups. In addition to identifying ethical issues, students must be able to actually solve ethics problems. Thus, in this course we taught students an ethical analysis tool, the Four A's. The Four A's was first introduced by Budinger and Budinger in the text Ethics of Emerging Technologies and is a strategy to systematically apply guidelines when assessing the multiple aspects of an ethical problem, so that alternate solutions can be generated and evaluated. Students were taught the steps of the strategy through lectures and reading assignments and then were asked to apply the technique to a specific case.

Based on student performance data, instructor observations, and student feedback, the case studies and Four A's strategy were effective methods for engaging students in ethics education. Case-based learning was used to convey the real-world importance of ethical issues. Students were able to utilize the Four A's strategy to thoroughly research, analyze, and solve ethics problems. Student feedback was overall positive, citing that having a structured framework with which to approach an ethics problem was valuable. Based on initial results, these techniques will help equip students with the understanding and the tools necessary to handle more complex ethical problems as they progress throughout their academic and professional careers.

Introduction

Learning how to identify and solve ethical problems is an essential component of an undergraduate engineering education. Students must be prepared to recognize and effectively deal with the inevitable ethical issues they will encounter during their educational and professional careers. Because ethics education is an important component of any engineering student's training, ABET criteria for the accreditation of engineering programs includes the requirement that graduating students be equipped with an understanding of professional and ethical responsibility and the ability to engage in engineering design while considering ethical, economic, environmental, social, and safety constraints¹. At the University of Washington, this requirement is satisfied by addressing ethical responsibility and engineering ethics problems throughout the core bioengineering curriculum.

Previous work has documented the advantages of integration of ethics education throughout the continuum of an undergraduate program, as well as the importance of teaching ethics within the context of the specific discipline². Thus, as part of the redesign of our undergraduate bioengineering curriculum³, we have elected to teach ethics at multiple points in the curriculum and in the context of the bioengineering discipline. Students are first exposed to ethical issues in the context of the bioengineering discipline in a recently-implemented course entitled Introduction to Bioengineering Problem Solving, BIOEN 215. One of the many goals of BIOEN 215 is to motivate students to engage in ethics problem-solving, through the use of real world case studies and the presentation of a strategic analysis tool useful for solving ethics problems. This course then serves as the foundation for the later bioengineering courses which also involve ethics instruction, including junior-level core courses and the Capstone Senior Design sequence.

In this paper, we present the approach utilized in BIOEN 215 to introduce students to bioethical issues, as well as a strategy for solving ethical problems. Important core learning outcomes for this course include: by the end of the course, students will be able to 1) identify ethical issues applicable to bioengineering and 2) apply engineering ethical analysis strategies and problem solving skills to design solutions to ethical problems. Our methods for realizing these learning outcomes involved a case-based approach. Students were presented with case studies involving a variety of ethical issues with real world relevance, in order to gain an understanding of the importance of considering ethics in bioengineering. We discussed the ethical issues involved in a variety of bioengineering-related areas, such as clinical trials, organ transplantation, and global health solutions. Students also learned a strategy for designing ethical solutions, called the Four A's, and were asked to apply the strategy to various authentic professional situations.

The Four A's was introduced by Thomas and Miriam Budinger as a systematic tool to help resolve dilemmas⁴. The Four A's strategy can be used by individuals or institutions to either design solutions to all types of ethical problems or to make decisions to prevent their occurrence. This technique provides an organized framework which assists one's thinking in-depth about an ethical problem and facilitates the selection of the optimal solution. Simply stated, the Four A's strategy is a systematic application of guidelines to thoroughly assess an ethical problem, so that multiple alternate solutions can be generated and evaluated. In effect, the Four A's serves as a useful decision-making guide and is especially valuable when an obvious best solution is not immediately evident⁴. The Four A's strategy calls first for the assessment of the multiple aspects

of an ethical dilemma, so that alternate solutions can be identified which may not have been apparent. Alternate solutions are then thoughtfully generated, and their consequences are evaluated in depth before deciding on a course of action. The Four A's involves the application of moral theories, prioritization of stakeholders, prioritization of duties, and an analysis of risk where appropriate⁴.

The major innovation of this work involves the documentation of the use of the Four A's strategy in an introductory bioengineering undergraduate course as an effective strategy for solving ethical problems. Previous work has cited the Four A's-containing text⁴ as one of the textbooks used to teach the ethics content of a biomedical engineering introductory course, but the Four A's strategy was not specifically discussed⁵. A biomedical textbook by Vallero describes the Four A's strategy as a systematic approach to reduce bias and conflicts of interest in decision making and applies it in the context of animal experimentation⁶. Though its usefulness is discussed, no measure of effectiveness is presented.

Related strategies have been shown to be effective in ethics education in engineering. For example, previous work has utilized a case-based approach to engineering ethics, where students were required to solve authentic engineering ethics problems using a set of guidelines that overlap with some of the components of the Four A's strategy. Students needed to consider the perspectives of the different stakeholders involved, generate multiple solutions, and ultimately decide upon a "best" solution⁷. Though quite different from the Four A's strategy, there is also a "Four Quadrants Model" for decision-making in medical ethics, which provides health care professionals with a method of considering all aspects of an ethical issue by considering quality of life features, medical indications, contextual features, and patient preferences⁸. To our knowledge, this paper is the first description of the implementation and assessment of the Four A's strategy as an ethical analysis tool in an undergraduate engineering course.

Description of the Four A's Strategy

Although ethical problems can be quite commonplace, the best solution may not be immediately obvious and the choices made may have serious, far-reaching consequences. The Four A's strategy is a systematic approach to ethical problem solving and provides a means for creating and assessing solutions to ethical problems. All types of ethical problems can be addressed with this strategy, including medical, professional, business, and research ethics. This approach provides an organized framework which assists one's thinking about a complicated ethical problem and helps one determine the optimal solution. It allows for the assessment of the multiple aspects of an ethical dilemma, so that alternate solutions can be identified which may not have been apparent. Alternate solutions are thoughtfully generated, and their consequences can then be evaluated before deciding on a course of action. The Four A's involves the application of moral theories, prioritization of stakeholders, prioritization of duties, and an analysis of risk where appropriate⁴.

Basic Steps of the Four A's Strategy⁴

- **Acquire Facts**: Define uncertainties and clarify ambiguities. Get the pertinent facts. It is important that decisions are based on factual information. This step is crucial in establishing what is known and unknown about the situation. Oftentimes, the

problem stems from the fact that we do not have all the information necessary to make an informed decision, but we may quickly decide on a course of action regardless. Ambiguities and assumptions must be identified if a well-informed decision is to be made. Possible questions to ask at this step include: What are the precedents involved? Can we talk to anyone else who has experienced a similar situation? What rules or guidelines have already been established which may be relevant (for example, by the NIH or FDA)? What are the facts involved? Are there risks involved? What are the uncertainties of this situation? How can we clarify those uncertainties?

- **Alternatives:** List alternate solutions. Develop alternate plans in parallel. Use the gathered information to develop realistic options and alternate solutions.
- **Assessment:** Assess the possible solutions according to the moral theories of virtue, justice, duty, rights, and utilitarianism. Who are the stakeholders involved (i.e. those that will be directly or indirectly affected by a decision)? How will those stakeholders be prioritized? During this phase, it is important to characterize all the potentially affected parties and the risks and benefits to each party involved with each solution⁶.
- **Action:** Decide on a plan for action. However, even after a solution is selected, keep alternate plans under consideration in case they are needed. Ethical decision making is not a static process, and different actions may need to be pursued as new information becomes available. Similar to the engineering design process, the initial solution may require revision and decision-makers should be open to new options⁴.

Participants

BIOEN 215 is a 3 credit hour introductory course taken by freshmen and sophomore undergraduates with an interest in bioengineering. Enrollment is capped at 125 students, though because of extensive demand for this course we are offering a smaller version of BIOEN 215 for a second time in the same academic year (2011-2012). The course consists of two lectures per week plus a discussion section meeting (25 students). At the time of enrollment in this course, the majority of students are not yet in the BIOEN major, though a small portion ($\approx 10\%$) are direct freshmen admits. BIOEN 215 precedes all other in-major technical course work, which commences Spring quarter of the sophomore year. This study includes results from the initial offering of BIOEN 215 in Winter 2011 (Jan.-March), and the subsequent offering in Autumn 2011 (Sept. – Dec).

Ethics Content in BIOEN 215

Case Studies

Case studies were first utilized to introduce students to the wide range of possible ethics problems in bioengineering and to illustrate the complexity of ethical challenges. Students were presented with authentic cases to make the material more tangible and relevant and to convince them that ethical problems occur in their field of interest. Case studies were also presented to specifically illustrate the complex nature of bioethics-related dilemmas, to address the underlying

misconception made by students that ethics is a “common sense” issue (based on feedback from the first offering of BIOEN 215) and that ethical analysis skills are merely “fluff.”

In lecture, students were first given a roadmap of how ethics was going to be addressed. As lower-division students still becoming acquainted with the biomedical field, it was important to first introduce students to the types of ethical issues they might encounter as future engineers, clinicians, scientists, etc. Then, students must also learn tools for designing ethical solutions to those complicated problems they may encounter. The ultimate goal is that we are producing well-rounded professionals who are equipped to deal with problems they encounter and who make positive contributions to our society.

In the beginning of the class, it is important to directly address the common misconceptions made by undergraduates about ethics, so that they are motivated to engage in the lesson. Over the years, we have anecdotally heard from students that they do not think they have to worry about ethics if they deem themselves a good person. Thus, students were told that being faced with ethical issues often has nothing to do with what kind of person *they* are; even if he or she is the most moral person, it still can be difficult to see a clear path to pursue. To convince them of this, students were presented with difficult lab situations which had nothing to do with what type of people they were (many of our students are engaged in or pursuing lab research opportunities, so these are tangible examples): 1) I’m not sure, but my lab mate may be altering her cell images in Photoshop. Is this acceptable? and 2) My mice seem to be in extreme discomfort, but when I told my P.I., she said to continue the study. What should I do? We also presented learning about ethics as something that we regard as important. The point was presented that sometimes one does not have all the information needed to make an informed, best decision. Decisions are not always clear-cut in complicated issues. Thus, we regard the ability to execute an ethical analysis as a technical skill, and not “fluff”.

Real world cases were presented in lecture which encompassed bioengineering-related ethical issues such as scientific misconduct, clinical trial ethics violations, conflict of interest, organ shortage and transplantation, responses from biomedical companies to medical device risk⁴, and clinical trials in developing countries. At the University of Washington, Public Health Service-funded researchers are required to participate in the Biomedical Research Integrity (BRI) Program, which addresses conflict of interest, data acquisition and ownership, peer review, responsible authorship, and research misconduct. As a BRI discussion leader, the BIOEN 215 instructor was able to incorporate real world examples from the BRI Program into the second offering of BIOEN 215, designed to specifically address the feedback from students during the first offering that ethics seems like a “common sense” issue (Table 1). BRI training is required for many of the positions these students are striving towards. This helped engage the students in the presented case studies because they were able to see the relevance to their future goals. A representative case study that was used to convey the complexity of biomedical ethics problems included one on the topic of peer review:

Overview: Peer review of scientific publications and grant applications is the primary means by which the biomedical community functions. Reviewers (usually anonymous) are selected to review unpublished, and confidential, materials.

Example Case: Your P.I. mentions an innovative new research methodology which she says will be of great value to your project. The new method promises to cut supply costs by 50% and will

allow you to have your data collected six months sooner than you had originally planned. You're thrilled to hear this, and ask your supervisor for the reference article where you can find the information on the method. "Oh," she responds, "it's not published yet. I just reviewed the paper describing the method yesterday."

Question posed to students: What should you do? Why?

After a brief pause to allow for student reflection, the instructor asked the students, "How many of you know exactly what you would do?" As expected, no one replied in the affirmative, although these students were trained in classroom participation. This helped convey to students that ethical problems do not always have a straightforward solution. The instructor recapped how this is a complicated situation. There are responsibilities to your own research progress, the integrity of the peer review process, your boss, your collaborators, the authors of the submitted paper, the editors of the journal of the submitted paper, etc. How can we then deal with this situation? This provides motivation for the Four A's strategy, to be discussed subsequently.

During discussion section meetings, guidelines for the use of human subjects and ethics of clinical trials were introduced. To gain an appreciation for why the ethics of human experimentation must be considered, students were presented with examples of what happened when ethics were disregarded, such as the Nazi experiments and the Tuskegee (U.S. Public Health Services) syphilis case study. The history and content of the established codes for ensuring ethical clinical trials, such as the Nuremberg Code and the Belmont Report, were discussed in the context of these case studies. Current guidelines for conducting ethical clinical trials, such as Institutional Review Board (IRB) approval, were presented. Students were presented with a case study of the first liver transplant⁴ and asked to analyze it in groups:

Overview: The donor for the first liver transplant was near death and comatose. The potential donor's condition deteriorated over the weeks of his hospitalization for a terminal illness. When it appeared that the donor's death was imminent, the surgeons took the recipient to the operating room and began preparing for the transplant procedure. Suddenly, the donor showed signs of pneumonia, for which the standard treatment is a massive dosage of antibiotics.

The ethical dilemma: treat the pneumonia and prolong donor's life, or jeopardize the hope of the recipient for recovery? What should be the duty of the doctors supervising the first experimental liver transplant? What would be the consequences of withholding treatment? What might be the consequences of treatment (i.e. might the donor or recipient be allergic to antibiotic penicillin)?

The last case study presented in discussion section was used to illustrate the importance of clinical trial guidelines. Students were given the facts surrounding the case study from 2001 involving the death of a healthy asthma study volunteer⁹ and were asked to discuss the case in pairs or groups of three, considering especially the information just presented on IRBs, informed consent, and the data safety and monitoring board. Students recorded the results of their discussions, addressing questions such as: What was the problem(s)? What should the researchers have done differently? What can we learn from this example? Do we have a full understanding of what happened? As a follow-up to the ethics material presented in lectures and discussion section, students were given an assignment to reflect on the proceedings (Appendix A). Students were encouraged to generate their own points of discussion, but possible points to discuss included: What do you consider to be some of the most important issues addressed? Did you find any aspect of the quiz section/ethics lecture particularly interesting/engaging/thought-provoking? Do any of the topics discussed have any relevance to you, directly or indirectly?

The Four A's

Case studies were first presented to create a motivation for an ethical analysis tool like the Four A's. If students believe that ethical issues are easily solved and straightforward, they will not understand the need for a systematic tool for ethical analysis. To further convince students that ethical issues are complex, the instructor cited that entire departments and core facilities at the University of Washington are dedicated to dealing with ethical questions.

The Four A's were introduced with a reading assignment from the Budinger and Budinger text⁴, and a subsequent short reading quiz to encourage reading of the material. Within the reading, the Four A's steps were outlined, and the strategy was applied to numerous case studies. Justification of the need for the Four A's was presented in lecture by the instructor, followed by an overview of the strategy and a review of the reading. A supplemental PowerPoint presentation on the moral theories discussed in Budinger and Budinger and how they play a role in the consideration of an ethical dilemma was also provided to the students via the course website. Students had the opportunity to practice the Four A's strategy through a homework assignment in which they were asked to apply the Four A's to a particular laboratory situation (Appendix B). The proposed case was based on a real-life example.

Assessment Results

Reflective Assignment: The main goal for this assignment was to provide students with the chance to reflect on the material discussed and place it into context. Students were evaluated on whether they provided a well-developed reflection on the implications and a personal evaluation of the proceedings (Appendix A). For the most part, students were able to synthesize the information presented and put it into the context of their own lives or future career goals. With the majority of students, obvious effort was put into contemplation, and insights were presented beyond just merely summarizing the proceedings. Numerous students cited an interest in pursuing ethics education further, through additional classes or a bioethics minor. This assignment was well-liked by students, and it provided a valuable opportunity for students to think introspectively and deeply about the material. During the second offering especially, this assignment served as an affirmation that students were gaining an understanding of the complexity of bioethics. The quantitative scoring results were as follows: out of 25 points, the mean score for the first offering = 24.8 ± 0.51 , second offering = 24.6 ± 1.3 .

The Four A's Assignment: In this assignment, students were asked to apply an engineering ethical analysis strategy to design solutions to an ethical problem (Appendix B). This assignment was used to formally assess ABET outcome (f), an understanding of professional and ethical responsibility. The quantitative scoring results were as follows: out of 25 points, the mean score for the first offering = 24.1 ± 1.4 , second offering = 23.3 ± 2.3 . We attribute these high scores to our model of high support, clear assignment expectations, provided rubric, and thoroughness of the information presented on the Four A's both during lecture and through the readings. Although students did quite well with this assignment, during the first offering students seemed to struggle most with the Acquire facts stage. This was rectified in the second offering by providing students with concrete examples of questions they might want to ask during that step. During the second offering, some students provided incomplete assessments of

their alternative solutions. Also, a few students had difficulty understanding the details of the situation described in the assignment, so the wording should be examined to see if any aspects can be clarified. Based on student performance overall, it appears that the required readings, lecture presentations, and supplemental material on moral theories posted on the course website were effective in teaching students the Four A's strategy.

Student Survey

Methods: After completion of the ethics content of the course, students were asked to fill out an anonymous survey during a discussion section meeting. Students were told that the teaching team was interested in obtaining feedback on particular aspects of the course and that a separate formal course evaluation would also occur at the end of the quarter. Surveys were completed by 97% of students (121/125) during the first offering and by 93% during the second offering (111/120).

Students provided feedback on their perceptions of the effectiveness of various ethics components of BIOEN 215 (Fig. 1). Students responded with an average rating for each question above a neutral level of 2.5. Note that the second question was added during the second offering of BIOEN 215, after additional case studies were incorporated to address student feedback that ethics seemed like a "common sense" issue.

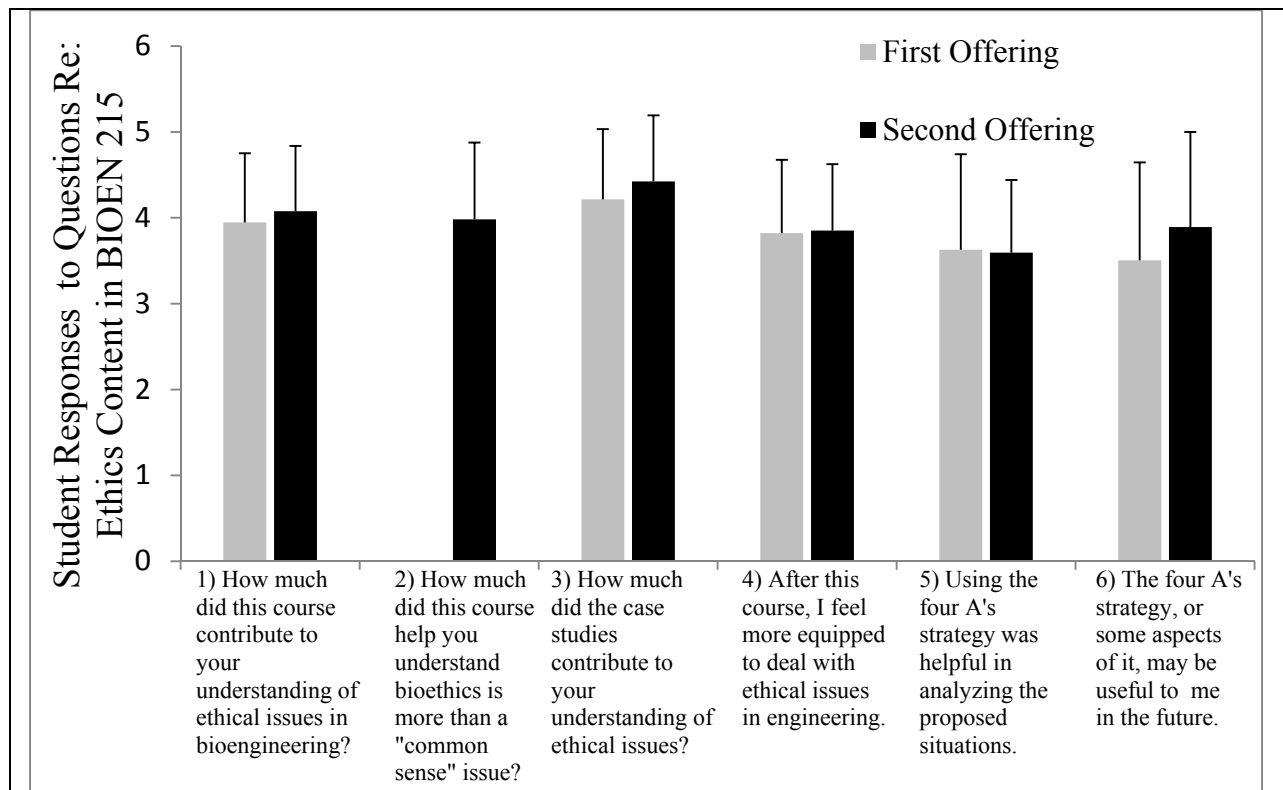


Figure 1. Ratings submitted by students in response to questions regarding the ethics content of BIOEN 215. Ratings are on a Likert scale: 5 = very much, 0 = not at all. Data are displayed as mean + standard deviation. The first offering of BIOEN 215 was in Winter quarter 2011; the second offering occurred in Fall quarter 2011.

Students also had the option to provide anonymous comments on the ethics curriculum of the course (Table 1).

Table 1. Representative comments submitted by students regarding the ethics content of BIOEN 215, including suggestions for improvements.

First Offering (Winter 2011):

- “This course is a great overview of ethical issues. I now want to take PHIL 242 Medical Ethics.”
- “To me the ethics seemed kind of obvious and common sense so it wasn't too helpful for me but it might have been for others.”
- “I found the ethics part of the course to be very interesting and thought it was well taught with strong case studies.”
- “I liked using the four A's to identify the best rational solution to a problem. When faced with an ethical issue the most rational answer may not be very clear at the beginning. So the four A's were helpful.”
- “Introduction of ethical concerns within the field of engineering was fantastic, and I learned a lot from the case studies we were shown.”
- “I think that perhaps more case studies could be useful. All said, great ethics curriculum!”
- “I feel aware of ethical issues, but will need more practical review of them to fully understand their value. The four A's assignment was helpful in solidifying the ideas.”
- “The four A's were useful but too hard to remember.”
- “I had never discussed ethics before this class so the introduction to ethical concepts and issues in health and medicine was very helpful to me.”

Second Offering (Autumn 2011):

- “I found the case studies to be extremely helpful to my understanding of the ethical issues. It was nice to be able to apply these concepts and see them applied in actual situations.”
- “I really liked the case studies as specific examples.”
- “Favorite class this quarter! Especially once we did the ethics section.”
- “I definitely learned a lot about the importance of ethics in the field of bioengineering.”
- “Very eye opening, helped me realize that ethics is a real issue in medical and research field, that ethics is more than common sense and being a good person.”
- “I am a big fan of the case study aspect of explaining ethical issues in bioengineering. It really helped to get the points across.”
- “Introducing the topic of ethics in bioengineering this early has been very beneficial to my learning.”
- “I really enjoyed the writing assignment about medical ethics.” [Reflective Assignment]

Student Feedback: Participation Points Index Cards

Methods: Throughout the quarter, students would complete short in-class activities during class time and submit their work on index cards, to encourage participation and increase student involvement and engagement in a large lecture class. During the last class meeting, students were asked to reflect on one or two topics addressed in BIOEN 215 that they felt will be useful to their future and submit those responses on index cards.

Students cited that they expected a wide range of topics taught in BIOEN 215 to be useful in their future endeavors, including the engineering design process, FDA regulatory issues, knowledge of scientific sources (how to navigate PubMed), effective scientific oral and written communication, clinical trial guidelines, effective group work skills, global health, and scientific literature analysis. Two of the most commonly-cited topics, however, were ethics and the Four A's strategy. Students described how they expected the introduction to biomedical ethics, as well as a strategy to solve ethical challenges, to be useful to their futures (Table 2).

Table 2. Representative responses related to ethics curriculum submitted by students to address: “What are 1-2 topics we discussed in BIOEN 215 that you feel will be useful to you in the future?”

Student Responses

- “The four A's strategy! This assignment caused me to rethink how I process ethical issues. I also think it will be very useful to me in the future as I pursue a medical degree.”
- “Ethics will also be useful in multiple career fields. Having a solid knowledge base of ethics and being able to generate ethical solutions will be a great help in the future.”
- “The importance of ethics in experimentation and implementation cannot be ignored and will undoubtedly be a crucial part of engineering work in the future.”
- “Learning about the ethics behind bioengineering was incredibly interesting to me. I had no idea that these kinds of ethical problems still persisted in the U.S. and as a bioengineering student I will need to know this.”
- “I had always assumed the creation of new ideas or products was straightforward. I didn't realize how much ethics came into play and all the regulations involved.”
- “One thing I learned this quarter was the importance of ethics in clinical trials. This was not a topic I had pondered before but it was very interesting to learn about.”
- “I also learned about ethics and ethical theories and how important they are to this field. The world of ethics has always been interesting to discuss but I have never been formally introduced to theory and specific engineering-related cases which will help me make better decisions in the future, when the time for me to make such choices comes.”
- “I will likely use the Four A's in other classes to assess certain situations.”
- “The most important part of this course, in my opinion, was the discussion about ethical considerations of research. Learning the 4A's system and ways to analyze ethical dilemmas was valuable.”
- “The four A's was a good way to evaluate all possible scenarios when it comes to making big decisions. This process will be useful in any career I plan to be involved in.”
- “I expect the Four A's to be useful in the future. Ethical issues arise often in medical fields, and often there is no obvious right response to them. Having a structured way to analyze these issues will be an invaluable tool.”

Discussion and Conclusion

Based on the direct assessment results (individual assignments), students were able to engage effectively with the ethics material of the course. Student perceptions regarding the ethics content, as assessed by an anonymous survey, appeared to be positive in both offerings of BIOEN 215. Encouragingly, student ratings appear to have an overall upward trend from offering to offering. Student feedback from the end of the quarter also indicates that the ethics curriculum in this course is being presented to students such that they can perceive its importance and applicability to their future endeavors.

Unfortunately, we do not have access to a student group which has not taken this new course, but based on student performance and perceptions, we are confident in the strengths of our approach to teaching ethics. However, as with any course, improvements can be made. Based on student feedback, one of the issues we would like to address next is attempting to make the Four A's strategy easier to remember. The written description of the Four A's assignment should also be reviewed for clarity.

From the first two offerings of BIOEN 215, we have learned that real world case studies engage students much more than lecturing on abstract ethical theories. Based on feedback from the initial offering, during the second offering textbook readings were used to teach students the different moral theories, and class time was used to engage them in compelling examples. Also, more case studies relevant to their fields of interest were incorporated, and the instructor made sure to cite when specifically students might need the presented material for the future. For example, many of the students are pre-med, so when the instructor cited that particular case studies were used for clinician ethics training as well, the interest level noticeably increased.

The findings of this study may be useful to guide the successful inclusion of ethics content for courses in which less time is dedicated to this topic. The importance of engaging students in real world case studies to first motivate their interest in ethics is key, and this can be accomplished with a selection of one or two compelling case studies, ideally related to their career interests. If case studies are given to the students ahead of time to read, during class time the instructor can lead a more informed discussion or review of the case(s). The Four A's could be presented during a discussion section class meeting, in which students also have a chance to practice the technique by applying the strategy to a provided case study. The methods described in this study are scalable in that the amount of time spent on each component can be adjusted depending on how much time is available to this topic. In a situation of a more technically-oriented course for example, the Four A's lecture and homework assignment could be replaced with the one discussion section in-class activity.

In conclusion, these methods were effective in conveying to undergraduates the necessity and complexity of solving bioethics problems. This study was conducted in a course with freshmen and sophomores, but these techniques seem appropriate for upper division students as well. Case studies with increased complexity and required background knowledge could be presented and analyzed. Based on a combination of direct assessments, student perceptions, and instructor observations, utilizing case studies along with the Four A's tool appears to be an effective strategy to engage engineering undergraduates in ethics education. These techniques serve to

equip students with the tools necessary to handle more complex ethical problems as they progress throughout their academic and professional careers. Thus, this work may prove useful for other programs interested in pursuing a similar technique for teaching biomedical ethics at their own institutions.

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Appendix A

Assignment: Reflection on Quiz Section Proceedings

Purpose: The purpose of this task is to give you an opportunity to reflect on the recent quiz section discussion regarding the use of human subjects. One of the goals of this course is to provide you with an understanding of professional and ethical responsibility (ABET outcome f), and to this end in quiz section we discussed the reasons why we must consider the ethics of human experimentation, through examples of case studies where ethical considerations have been disregarded. We learned about the established codes for ensuring ethical experimental trials involving the use of human subjects. We also discussed many of the ethical issues that are involved in the bioengineering discipline during the following class lecture, including techniques that can help us deal with ethical problems that we may encounter.

Assignment Description: Write 2 paragraphs regarding *your* thoughts of the proceedings. Please note that the quiz sections proceedings and ethics lecture material are fair game for this assignment. You are encouraged to be thoughtful and generate your own points of discussion, but possible questions may include: What do you consider to be some of the most important issues addressed? Why? Did you find any aspect of the quiz section/ethics lecture particularly interesting/engaging/thought-provoking? Do any of the topics discussed have any relevance to you, either directly or indirectly? What are a few take-home messages that will be important to retain for your future endeavors? Do you think we have adequate measures to prevent ethical violations during human experimentation? Do you have any concerns about the regulations the U.S. has established for trials involving human subjects?

Grading Rubric				
Dimension	Excellent	Competent	Needs Work	Points and Comments
Thinking/Content	(15-13 pts.) Provides a well-developed reflection on implications and personal evaluation of the proceedings. Obvious effort put into contemplation; insightful and creative points are presented beyond just merely summarizing the proceedings.	(12-11 pts.) Conveys a genuine effort to reflect on the implications of the proceedings; may contain too much summary and not enough detailed analysis or reflection.	(10-0 pts.) Little to no effort demonstrated; may contain only a summary of the proceedings of the quiz section; little to no analysis or insightful considerations provided.	/15
Writing quality	(5) Overall absence of misspelled words; writing style is clear, without superfluous wording.	(4-3) Some words may be misspelled; writing style is satisfactorily clear and concise but may contain obvious superfluous wording and portions which are difficult to understand.	(2-0) Many misspelled words; writing is hard to understand; may be excessively wordy	/5
Organization and Formatting	(5) Assignment is well-organized and easy to read. Assignment components are presented in a logical order.	(4-3) Assignment components are presented in an overall logical order; some formatting aspects (font, spacing, etc.) may be inconsistent or unpolished.	(2-0) Assignment is disorganized and difficult to follow.	/5
TOTAL:				/25

Appendix B

Assignment: Ethical Analysis using the Four A's

Purpose: One of the goals of this course is to provide you with an understanding of professional and ethical responsibility, as well as an appreciation for how ethical issues are continually raised in the area of biomedical research. In this class, we are providing you with tools that you can use throughout the rest of your undergraduate career and in subsequent endeavors. Here, you will apply a formalized design strategy to the following situation in order to decide on an ethical course of action.

The Situation: Fast forward 12 years or so. You are a professor at the University of Washington. You have graciously allowed a student to work in your lab to complete his Capstone Senior Design project. Your new student is doing his capstone project which picks up where a previous student left off. He wants to take the protocol she (the previous student, who has graduated) developed for a diagnostic assay and build a prototype microfluidic device that will perform the same function at a fraction of the cost. Unfortunately, he cannot reproduce the results of the protocol she described in her capstone paper. He looks through her lab notebook in search for some guidance, and reads with interest how she redesigned her protocol repeatedly in response to various failures over winter and spring quarter. Midway through spring quarter, she finally arrived at the protocol described in her capstone paper. However, in both attempts to execute this protocol by your dedicated and very-experienced post-doc, the data was inconclusive and not too different from those your new student is now getting. You and your new student can't find the convincing data that appear in her capstone paper, or the electronic raw data for this experiment in the computer files with the rest of her electronic data.

Assignment Description: In approximately 1 page single-spaced (merely a guideline, not a mandatory limit or minimum): Describe how you, as the professor, would use the design strategy to address this problem. Apply the technique of the Four A's to the situation presented above. As with all ethics-centered situations, there are a variety of options. You will not be graded on which particular option you choose to pursue, but instead your use of the Four A's strategy to logically design a solution for the situation. Outline the steps you would take, and come up with outcomes for each step along the way, as appropriate. (These outcomes are obviously hypothetical ones that you generate.) Your final solution can depend on information or outcomes resulting from previous steps, but you must describe how. Finally, in 1-2 sentences, describe what ethical issues in research this case study addresses. Does it highlight the importance of any lab practices in particular?

Grading Rubric

Dimension	Excellent	Competent	Needs Work	Points and Comments
I. Acquire Facts	(5) Describes insightful questions that can be asked regarding policies, precedents, resources, interviews with individuals involved, etc. Explores many different directions which may be pursued.	(4-3) Displays mid-level effort to generate a variety of types of questions that should be pursued.	(2-0) Displays minimal effort to outline what types of information should be acquired; only 1-2 questions may be proposed, or those proposed may not be relevant to situation at hand.	/5
II. Alternative Solutions	At least three alternatives are presented which make sense for the described situation; alternatives encompass a wide variety of possible actions.	Relevant options are proposed but there may be less than required.	Distinct alternatives are hard to discern or are unclear; possible actions presented may lack sufficient detail.	/5
III. Assess Each Alternative	Provides thorough outline of the possible ramifications and consequences (both positive and negative) of pursuing each alternative solution, at a variety of levels; insightful elaboration of who the solution will impact and how.	Provides a satisfactory outline of the possible ramifications and consequences of pursuing each proposed alternative solution, but may be lacking in some detail, may be incomplete.	The outline of the possible ramifications and consequences of pursuing each alternative solution is not well-developed.	/5
IV. Action	There are many possible actions, but the final action selected should be based on evidence collected and rules (student may make assumptions about the results of the acquiring facts stage, rules, etc.). Justification for selection of that action is provided.	A final action is selected but a justification for that selection is lacking.	A final action may or may not be selected; no reasoning is provided.	/5
Summary of issues presented in case study	(2) Contains 1-2 sentences describing how this case study addressed the importance of specific scientific/laboratory practices.	(1) Attempts to describe how this case study addressed the importance of scientific/laboratory practices; discussion may be vague or unclear.	(0) Not included.	/2
Organization and Formatting	(3) Assignment is well-organized and easy to read (sections and headings are encouraged!). Assignment components are presented in a logical order.	(2) Assignment components are presented in an overall logical order; some formatting aspects (font, spacing, etc.) may be inconsistent or unpolished.	(1) Assignment is disorganized and difficult to follow.	/3
TOTAL:				/25