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Developing Engineering Students' Moral Reasoning Skills Using Problem-Based Learning

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Abstract: Problem-Based Learning has become an increasingly popular instructional method for a variety of disciplines at all levels. Many studies and meta-analyses of these studies have shown the efficacy of this method for developing knowledge and skills. I adopted this method for teaching Engineering Ethics at Carnegie Mellon University, which has as its main course objectives the development of moral reasoning skills, as well as collaboration and communication skills, with special attention given to ethical dilemmas that may arise in the normal course of an engineer's professional career. In the most recent iteration of the course, I used the Engineering and Science Issues Test as a pretest and posttest to test the development of my students' moral reasoning skills over the course of the semester. Based on the results of these tests, I argue that the students in my Engineering Ethics course did in fact significantly develop their moral reasoning skills.

Introduction

Most, if not all, professional engineering societies, like the American Society of Civil Engineers, has a code of ethics that it expects its members to follow. And, for nearly every society, the first canon of ethics is a variation on: "Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."[1] Accordingly, the Accreditation Board for Engineering and Technology (ABET) requires all engineering schools to teach ethics in their curriculum.[2]

Most educators agree that engineering ethics must not be taught as a list of rules to follow, nor as merely an investigation of classic modern moral theories. Rather, it should be a matter of developing students' moral reasoning skills:

> To be able to engage in an ethical discussion, one requires appropriate decision-making skills—skills to understand and recognize moral issues, and skills to find

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> solutions to moral problems. A good scientist will increasingly need these skills in the future.[3]

There is some controversy, however, about how effective ethics courses can be in developing engineers' moral reasoning skills. After all, people everywhere develop moral reasoning skills as they mature with or without formal ethics instruction.[4] Many researchers have found, however, that formal ethics instruction supports and even increases the development of these skills, for a variety of different types of instruction.[5] When first developing my own course in engineering ethics at Carnegie Mellon University (CMU), I developed learning objectives and then decided what kinds of learning activities would best guide my students to meeting these objectives. The pedagogical strategy I chose was Problem-Based Learning.

Problem-Based Learning

For the past several years, I have implemented a "flipped" classroom model using Problem-Based Learning (PBL) for most of my classes.[6] PBL has been used widely since its introduction into medical school curricula about forty years ago. Its efficacy is well-documented.[7] Since then, it has been used across academic disciplines and levels, including elementary, middle, and high schools, as well as in colleges, universities, and professional schools.[8] It has been used in business,[9] economics,[10] engineering,[11] pre-service teacher education,[12] computer science,[13] legal studies,[14] biology,[15] chemistry,[16] and physics,[17] among others.

In general, PBL has been touted as a good instructional strategy for developing critical thinking skills, complex problem solving skills, research skills, writing skills, and cooperative skills.[18] Several meta-analyses have shown that PBL is equal or superior to traditional instructional strategies for developing students' knowledge and skills.[19] They have also shown that students who take PBL courses retain more knowledge and skills in the long term than do students taught in traditional ways.[20] In addition, PBL is nearly universally preferred by instructors and students.[21]

An overview of the basic methods of PBL can be found in various sources, but the basics can be summarized easily by contrasting it with many traditional methods of instruction.[22] A traditional instructional strategy is to teach students abstract or theoretical material and then ask them to apply that knowledge to case studies to enrich and demonstrate their learning. In PBL, the situation is reversed. The learning begins with an ill-structured, problematic case study, and the abstract or theoretical knowledge is learned in the process of trying to solve the problem. The students then work in groups to solve the problems posed. The problems are the key to a successful course, so a lot of thought has to be put into their construction and into the guidance the students receive in their pursuit of the best solution. Several authors have indicated that the best problems for PBL have the following characteristics:[23]

1) They draw students in and demonstrate the importance of the material.
2) They ask the students to make decisions or judgments.
3) They are messy with no immediately clear answer and several possible good answers.
4) They are complex enough that simple "divide and conquer" won't work.
5) They are broken into chunks that build on each other, getting pointed feedback at every step.

So, in general, PBL is a good pedagogical strategy. Is PBL a good strategy for teaching moral reasoning? Specifically, would an engineering ethics course employing a problem-based curriculum aid engineering students in developing their moral reasoning skills?

Using PBL to Teach Engineering Ethics

One skill I help students develop is the ability to recognize the ethical dimensions of myriad situations. I want the students to think seriously about the ethical issues that may arise for a professional engineer. I ask my students to solve problems that reflect the reality of their future profession.

While they deliberate in groups, students conduct their own research and ultimately make a decision about the best course of action. For example, they must identify the stakeholders, the stakeholders' interests, and the arguments each stakeholder might give for a particular course of action. Based on these arguments, the group argues for its decision about a course of action. Throughout this process, the groups submit regular writing assignments on which I provide rapid feedback.

An example of a PBL assignment that I give to students in my engineering ethics course is provided in Appendix A, but let me here describe the general characteristics of these assignments. First, they arise from areas of research that Carnegie Mellon University faculty are working on currently, and they reflect real decisions that these research groups have made or have to make.[24] The students see the relevance and importance of the topics immediately. Second, the final step in each problem is for the students to decide, as a group, what should be done. This can include deciding whether they, as engineers, should work on a particular project, which kinds of safeguards must be built into the design, or which specific recommendations to make to the government, industry, or ethics board.

Third, the problems require the students to identify a variety of stakeholders and consider their points of view in their final decision. This includes identifying the particular values and interests of stakeholders such as the general public, industry, government agencies, producers, consumers, and so on. Often these groups have incommensurate values and interests, so solutions to the problem are neither obvious nor immediate. Fourth, in order to do well, the students cannot merely divide up the work and string together their results. Rather, the students must synthesize their work, critique each other's writing, and come to agreement on several different points in order to succeed.

Lastly, the students are given milestone deadlines on their way to solving the problem so that they can understand the general method for tackling messy, complex ethical issues. In fact, these problems teach the students not only how to solve ethical problems as professional engineers but also how they can go about solving complicated ethical problems in many other aspects of their lives.

More specifically, the main learning objective is for students to develop their moral reasoning skills, which, for the problems considered in my course, include the ability to:

1) Identify and analyze the ethical aspects of particular problem situations in the domain of engineering practice and research.
2) Describe and explain how each problem situation would look from various points of view, with a full and fair-minded understanding of how each point of view makes sense on its own terms.
3) Describe and explain how ethical frameworks have bearing on each problem situation.
4) Effectively collaborate with others in analyzing problem situations and in generating several distinct options.
5) Present a critical consideration of each option that is well balanced and theoretically informed.

I first taught the course in the fall of 2015. It appeared to go very well. So, the next time I taught it (spring of 2017), I wanted to confirm that my objectives were being met with robust assessment. Specifically, I wanted to know whether and to what extent my students were learning the knowledge and skills I was targeting. To answer this question, I developed a study to test the following hypothesis: Engineering students will improve their moral reasoning skills over a semester of engineering ethics.

Participants and Method

Nineteen students (six women and thirteen men; three freshmen, nine sophomores, four juniors, and three seniors) from Carnegie Mellon University's College of Engineering enrolled in Engineering Ethics in the spring of 2017. They all took a pretest during the first week of classes and a posttest during the last week of classes.[25]

Materials

Both the pretest and the posttest consisted of the Engineering and Science Issues Test (ESIT). This test is an instrument developed by Jason Borenstein, Robert Kirkman, and Julie Swann for assessing the ability to apply general moral principles to particular situations relevant to science and engineering.[26] It is modeled on the second generation of the more general Defining Issues Test (DIT-2).

The original DIT was based on Lawrence Kohlberg's theory of moral development, and DIT-2 is based on refinements made to this theory.[27] James Rest and Darcia Narvaez[28] abandoned the Kohlbergian linear series of stages and embraced a theory that views moral development in terms of three conceptual schemata that may overlap in the thinking of any one individual:

1) The pre-conventional schema (characterized by narrow personal interest).
2) The conventional schema (characterized by an appeal to duty and to maintenance of the existing social order).
3) The post-conventional schema (characterized by the search for moral ideals on which a social order ideally ought to be based).[29]

Borenstein and his colleagues at Georgia Tech modified the DIT-2 to target the assessment of the moral development of science and engineering students. The test consists of six cases reflecting an "ethically problematic situation that a scientist or engineer might reasonably expect to confront in professional practice."[30] After each case is a list of questions representing different issues related to the case. The students are asked to rate each question in terms of the importance of the issue it raises, from 1 (great importance) to 5 (no importance). The students are then asked to rank the four issues they consider to be most important for deciding the case.

Results

The scoring of the ESIT represents the prevalence of pre- and post-conventional thinking in the students' moral considerations. Without going into details about the scoring procedure (see Appendix B for more detail), two numbers are calculated for each of the cases. The "Pscore" represents the number of post-conventional issues the student listed in their ranking of the top four issues as a percentage of the number that they could have listed. The "N2score" represents the relative importance the student attaches to pre-conventional issues (as opposed to post-conventional) issues. Thus, if a student moves away from pre-conventional thinking toward post-conventional thinking over the course of the semester, then his or her Pscore and N2score will increase over the course of the semester.[31]

Recall that the hypothesis is that the students' moral reasoning skills improved over the course of the semester. This hypothesis was tested by determining whether

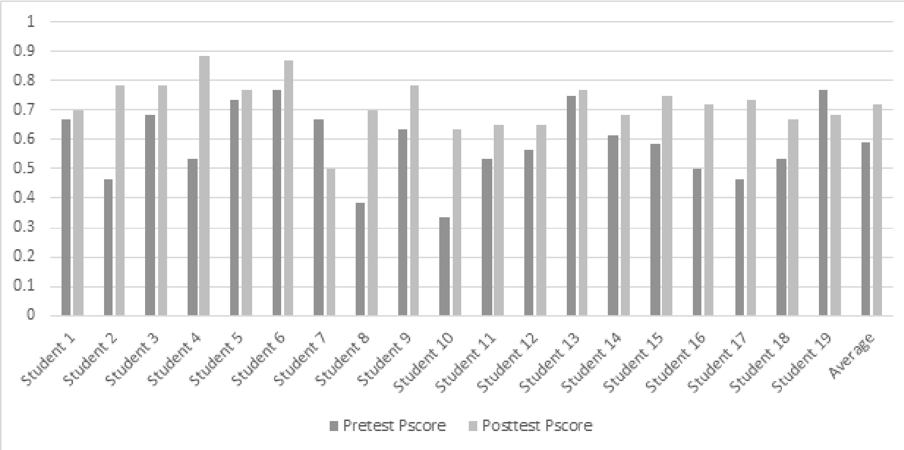

Figure 1: Comparison of Pretest Pscores and Posttest Pscores for Each Student and Average of All Students

the average gain on both the Pscores and the N2scores of the students from pretest to posttest was significantly positive.

From these results we can see that the students' average gains from pretest to posttest were positive for both the Pscore and the N2score. In order to see if these gains were significant, a two-tailed t-test was performed on the average gain for each measure. Additionally, in order to determine how large the effect was, Cohen's *d* was calculated on the average gain for each measure. Cohen's *d* measures by how many standard deviations the students improved from pretest to posttest, so a Cohen's *d* of 0.2 means that the gain from pretest to posttest is two tenths of a standard deviation. In comparing effect size, 0.02 is considered to be a small effect, 0.05 is a medium effect, 0.08 is a large effect, and 1.1 is a very large effect.

Limitations

There is, obviously, one important point about this study that is worth scrutiny. While the results are very positive, we are not comparing them to improvements in moral reasoning skills that an average engineering student (who did not take Engineering Ethics at Carnegie Mellon University) would gain over a semester. Nor are we comparing them to improvements in moral reasoning skills that an engineering student taking a different ethics course at Carnegie Mellon University, or to an engineering student who did take Engineering Ethics from either another instructor or from me, using a non-PBL curriculum, would gain over a semester. The main reason we did not design a study with these comparisons is that I am the only person at CMU who teaches Engineering Ethics, and I have taught it only twice, the same way each time.

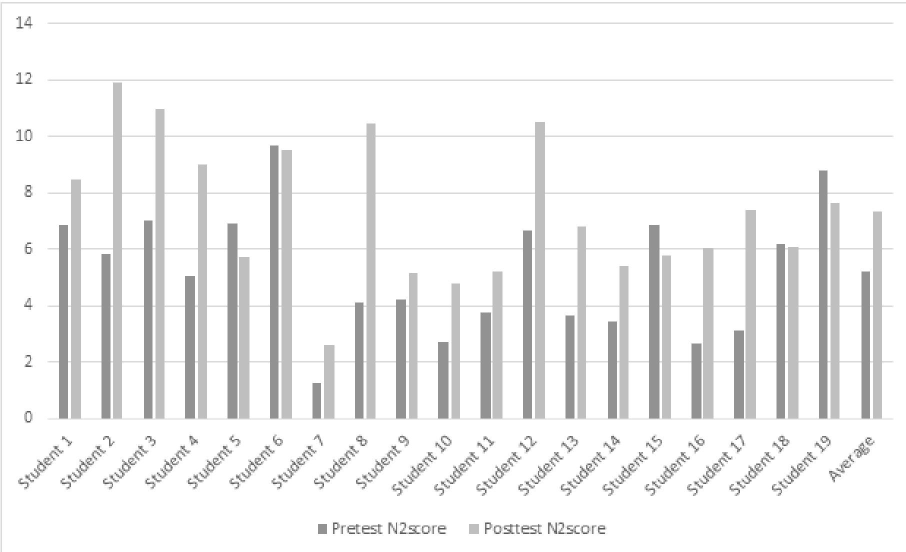

Figure 2: Comparison of Pretest N2scores and Posttest N2scores for Each Student and Average of All Students

Thus, this study should be regarded as only one data point in the general effort to test the effects of PBL on the development of moral reasoning skills and not as broadly confirmatory. As such, while it is highly suggestive, additional confirmational studies are needed.

Discussion

One set of skills I would like the engineering students to acquire or improve by the end of my engineering ethics course can be loosely labeled "moral reasoning skills." This set of skills includes the ability to investigate a case that could represent a situation that the students would encounter during their careers as professional engineers. In particular, it includes the ability to recognize an ethical dilemma, understand the moral issues involved, develop a variety of possible solutions, and argue for the solution thought best. With respect to the moral issues involved, mature moral reasoning considers issues concerning the ideal principles on which a society *ought* to be based to be more important than issues concerning the narrow personal interests of the agent.

As ethical questions in engineering practice are often complex and messy, PBL was a good candidate curriculum to achieve these goals as it emphasizes real-world problems and challenges to students to thinking creatively about ways to solve these problems while considering the wide variety of stakeholder interests that might be involved.

As Table 1 shows, the average gains made by CMU's Engineering Ethics students in spring 2017 from pretest to posttest demonstrated large to very large, statistically

Table 1: Statistical Significance and Effect Size of the Gain from Pretest to Posttest for Each Measure; *p‹0.01

Engineering Ethics Spring 2017	
Gain Pscore	0.13*
Cohen's d	1.25
Gain N2score	2.2*
Cohen's d	0.9

significant effects. Students in this class shifted their thinking substantially from prioritizing pre-conventional issues to prioritizing post-conventional issues, and so significantly improved their moral reasoning skills over the course of a semester.

There are several potential reasons (possibly overlapping) for this improvement. First, students must develop a facility with different frameworks for moral reasoning. They must wrestle with the competing claims of cost-benefit analysis, human rights and dignities considerations, visions of the kind of engineer they want to be, and caring for others in their families, neighborhoods, and communities. Second, students are required to consider ethical issues from others' perspectives, which involves understanding how the values of others might differ from their own, deciding how to take these differing values into account, and determining the best "all things considered" actions to take. Finally, students must work together to solve problems, which includes thinking concretely rather than merely abstractly about others' perspectives and values, finding consensus on the application of various moral frameworks to particular situations, and entertaining solutions other than their own.

The primary educational value of this study is twofold. First, the results suggest that it is possible to significantly improve students' moral reasoning skills over the course of just one semester. This finding is important since many studies have shown that college students in general improve their moral reasoning skills only half of a standard deviation during all four years of college.[32] This discouraging statistic, however, may be much improved by more students enrolling in courses that explicitly focus on the development of moral reasoning skills.

Second, these results suggest how applied ethics teaching may be scaled up to large classes. Ethics, especially applied ethics, is often taught by having students discuss readings and ideas with other students in class but ultimately arguing for particular solutions to ethical problems individually, in isolation. While this is not *prima facie* problematic, this kind of teaching does not scale well to larger classes. The results of this study indicate that improvements in moral reasoning can happen in a course in which the majority of the learning is peer-to-peer and occurs in small teams. Having students work in small teams, teaching each other, and working to create solutions is something that could happen in a class of fifteen or a class of 100 or more. Not only does this comport with recent advice to make learning more student-centered, it also cuts down on the amount of grading an instructor has to do.[33]

For example, I usually form groups of four to five students. In a fifteen person class, this cuts grading to three or four assignments per week. In a 100-person class this could amount to cutting weekly grading from 100 to twenty assignments. This reduction allows more time for instructors to give detailed, thoughtful feedback to students during every stage of their projects, at a time when students will use the feedback and discuss it with others. This way of teaching is not, of course, a panacea, but I believe that it serves as a proof of concept in a time when many departments are increasingly concerned with enrollments.

This study also points to future directions for this research. The first would be to compare the improved moral reasoning skills of students who take a course employing PBL with students who take a comparable course using more traditional pedagogy, pedagogy involving predominantly lecture in class and/or assignments where students learn concepts first and then apply them to a fairly simple case. This could be tested by randomly assigning students to one of two sections of the course for a semester and comparing the results of the ESIT taken at the beginning and the end of the semester.

Additionally, a comparison of students in a PBL engineering ethics course and students who do not take engineering ethics at all should be illuminating. This could be tested by having a randomly-formed mixed-cohort group of engineering students take the ESIT as a pretest at the beginning of a future spring semester and then as a posttest at the end of that semester. Then we could compare the students who were taking an engineering ethics course with students who were not.

Additional research could compare student gains in an engineering ethics course that uses PBL as the central pedagogy of the entire semester to the student gains in an engineering ethics course that uses PBL for only one or two assignments. Again, ESIT pretest and posttest comparison could be used to generate data.

Furthermore, with the implementation of "ethics-across-the-curriculum" in many engineering schools, individual engineering instructors may also want to incorporate ethics education into their regular classes, as currently not all of their students can take a semester-long engineering ethics course. We would like to know whether students' moral reasoning skills would improve, perhaps incrementally, using short, concentrated PBL units. And if so, we would like to know whether this improvement can accumulate over the four years of the students' undergraduate education to rival the significant gains associated with a full semester ethics course using PBL. This could be tested by having a randomly-formed mixed-cohort group of engineering students take the ESIT as a pretest at the beginning of the first year and then as a posttest at the end of the last year in the program. Then we could compare the improvement of the students taking just the ethics-infused engineering curriculum with the students who take that curriculum plus a PBL course.

Appendix A

Problem: Designer Babies

Story[34]

The research team assembled quietly in the lab. There were some difficult decisions to be made today.

Kelly, a new research assistant, looked forward to the discussion. Privately, she hoped Dr. Wagner and the rest of the team would agree to help the couple that had appealed to them.

"Good morning, everyone," Dr. Wagner began the meeting. "We have a lot to talk about. I'll summarize this case for those of you who may not have had time to read the file. Larry and June Shannon have been married six years. They have a four-year-old daughter named Sally who has been diagnosed with Fanconi anemia. Sally was born without thumbs and with a hole in her heart. Shortly after her birth, she began suffering symptoms related to impaired kidney function and digestion that have only increased in severity. Fanconi anemia is a progressive disease that often results in physical abnormalities and a compromised immune system. Sally needs a lot of special care and has already had several surgeries. She can't digest food normally or fight off infections as easily as a normal child would. If she doesn't receive a bone marrow transplant, she will develop leukemia and die, most likely within the next three to four years. Neither Larry nor June had any clue they were both carriers of this disease."

"A frightening diagnosis," said Kevin, a research technician.

"Difficult to live with, as well. Not only will they probably lose this child, they must be crushed about the possibility of having another child with this illness," commented Liz Schultz, the team's postdoctoral researcher in gynecology and fertility.

"Exactly their problem," continued Dr. Wagner. "The Shannons are interested in having another child and have approached us regarding pre-implantation genetic diagnosis (PGD). They are aware of the risks and the odds of success. They are anxious to begin the process as soon as possible.

"Kelly, you're new to the team, so let me summarize the PGD process for you. It's a three-step process, with chances of failure and complications at each step. First, in-vitro fertilization (IVF) is performed. Some of June's ova would be removed and fertilized with Larry's sperm outside of June's womb. If this procedure works, we should have several viable, fertilized embryos. Our second step is to perform genetic analysis on the embryos, removing a cell from each and testing for the presence of the Fanconi anemia genes. If we find embryos that are free of Fanconi's, we can then perform the third step: implanting the healthy embryos back into June's uterus."

"Wait a minute," said Kelly. "How many embryos are we talking about? They just want one child, not a half dozen."

Dr. Wagner laughed. "Yes, I know. But during the in-vitro fertilization and implantation processes, we almost always have embryos that do not survive. There is only about a 23 percent chance of any implanted embryo thriving. There is a better chance for a positive outcome when we remove and fertilize multiple ova. In this particular case, the odds of a multiple pregnancy are very small, given the limitations on the ova we will be able to implant."

"OK, I know I don't understand all of this. But how can Mrs. Shannon produce that many eggs all at the same time?" asked Kelly. "She wouldn't normally do that, would she?"

"No," said Liz. "So, before we even begin any of these procedures, June would have to take hormones to increase the number of ova she releases. As Dr. Wagner said, there are risks involved with every step of this procedure. Hormone therapy can have some side effects, including mood and cognitive effects. Some women suffer physical complications as well, although this is relatively rare. There are some studies that link hormone therapy to increased risks of ovarian cancer, although there is other research that contradicts that."

"Plus," Dr. Wagner added, "along with the risks to June, there is no guarantee that the procedure will be successful. Many couples must undergo the IVF procedure more than once before the implantation is successful in producing a healthy, full-term baby. In this case, it will be even more complicated because we cannot use all of the fertilized embryos but must limit ourselves only to those that are free of Fanconi anemia."

"But we've done several of these types of procedures with a pretty high rate of success," said Kevin.

"Why should this one be different? You've screened the couple, right, and you said they're aware of the risks?"

"Yes, but this case is very complicated." Dr. Wagner sighed. "The Shannons have requested not only a Fanconi-free child, but one that will be a perfect bone marrow match for Sally. Sally's illness may be treated with a transplant of healthy cells into Sally's bone marrow. Because Fanconi patients are so fragile, however, the donor's cells have to be a near perfect match, and that's hard to find. Siblings are the best bet. In the meantime, Sally's condition is deteriorating. The Shannons naturally want to give Sally as many years of normal life as possible, so they want to take aggressive action. They want to cure Sally's disease by planning and creating another child with specific genetic markers."

"How would that work?" asked Kelly.

"You've heard of stem cell research?" began Liz. "Stem cells are special cells that can produce all the different organs and tissues of the human body. They are found in embryos or fetuses and are usually obtained for research from embryos that die or are rejected in fertility procedures. That is the kind of research that has been so politically controversial lately. But a less potent type of stem cell is also found in adult humans and can also be obtained from umbilical cord blood. If we were to help the Shannons, and the procedure was successful, the blood from their new baby's umbilical cord could be used for Sally's bone marrow transplant, resulting in no injury at all to the baby and a possible cure for the worst symptoms of Sally's illness."

"The Shannons are suggesting that we perform the PGD procedure as we normally do, but select only those embryos that are both free of Fanconi anemia and are also a perfect match for Sally," said Dr. Wagner. "This presents some real ethical dilemmas for us. We have never tried this before. People have had PGD done to detect and prevent a variety of illnesses in their children, just as we have done here before. But what we are proposing now would be selecting for a specific combination of genetic traits, a combination that will not benefit the planned child but will save an existing child. We will be selecting an embryo and then using it essentially as a blood donor for its sibling. It will be umbilical cord blood, which would be discarded anyway, but it's still a controversial procedure. If we agree, it also means we will be destroying embryos that are perfectly healthy but are just not a match for Sally. I'm interested in pursuing this, but these are serious issues to consider. Not the least of which is that we may have trouble getting it approved. Before I run it past the review board, I want to know how you all feel about trying it."

"Well, I say go ahead with it. It will be a genetic breakthrough. In time, we'll be able to prevent all kinds of problems with this procedure. Why not start now?" urged Kevin. Another doctor on the team, who had remained silent, nodded her head in agreement.

"I'm not sure yet how I feel about this," said Liz. "I feel a little uncomfortable with the precedent this might set. We'll be opening the door to who knows what type of genetic selection. Do we want the responsibility for that?" A couple of others on the team seemed to side with her.

"Yes," said Kelly. "But think about the poor Shannons. And especially Sally. Does she deserve to suffer just because we're arguing about ethical problems of the future?"

"Well, it sounds like we all need to talk about this some more before we can reach a real consensus," Dr. Wagner concluded. "I don't want to start on a case this important without everyone's agreement."

Question

In a real case very much like the above story, the procedure worked, and Sally was treated with material from the umbilical cord of her new baby brother.

But now consider a twist. You are part of a team that is looking into the possibility not just of selecting embryos that have (or don't have) certain genetic traits, but of being able to actually change the genetic code of the embryos before implantation.

As engineers, you could conceivably develop the technology for any kind of genetic manipulation. Are there some kinds of genetic manipulation that you should pursue? Are there some kinds that you should not? What should you do?

Assignment

Tuesday (in class)

- Read the entire program assignment.
- Develop a team plan.
    - Determine the role each member of your group will take on for this problem.
        - Project manager, note/minutes taker, assignment submitter, etc.
    - Create a task schedule.
    - Create a Google Doc, or something similar, for your collaborative work.

Thursday (in class)

For Friday's assignment begin applying the ethical cycle:

- Develop a Moral Problem Statement:
    - Identify possible actions you could take.
    - Formulate the moral problem statement: "Which of the possible actions should we take?"
- Analyze the Moral Problem:
    - State the relevant facts (that you know so far) given in the description above.
    - Identify all the stakeholders (individuals and groups who are either interested in the results of this research or are affected by possible ramifications). Try to identify as many stakeholders as possible. Everybody concerned should be considered.
    - Discuss the interests, needs, world views, and values of all these stakeholders.

Due Friday

Submit your moral problem statement question and your list of stakeholders. Based on your discussion, formulate for each of the stakeholders one (or more) of their positions in the form of a single statement that says very specifically what the stakeholder thinks you (as an engineer) should do. Include a bibliography of all the sources used.

Between Thursday's class and Tuesday's class (individually at home)

The goal of this assignment is to understand each stakeholder's position as plausible and legitimate. Investigate the case from each stakeholder's perspective (be especially careful of those positions that you do not personally share), searching for material that allows you to understand each stakeholder's position and the reason for holding that position. Remember that reasons have to include moral principles that are based on the values of each stakeholder.

Tuesday (in class)

Discuss the research on each stakeholder's position, and develop an argument for each position that the stakeholder might plausibly give. When formulating the reasons each stakeholder would give for the position, reflect upon the following considerations:

1) What is the current status of scientific knowledge available for this case?
2) What are the ethical principles and values on which the stakeholder's arguments are based?
3) Are there any historical precedents to the case? Are there historical analogies to similar or related problems, including past and current policy resolutions? What was their rationale?
4) What might happen if your stakeholder's suggestion of what should be done becomes realized? What are possible consequences and impacts?

Whenever a reflection on these points changes your understanding of the stakeholder's perspective on the case or suggests another position that you find more convincing, change the main conclusion of your argument (which presents what should be done according to the stakeholder in question) and revise your argument accordingly.

If additional stakeholders come to your mind, add them to your original list, formulate their positions, and develop another argument diagram to justify these positions as well.

Thursday (in class)

Begin creating a separate argument diagram to represent each of the arguments for the stakeholder positions you developed on Tuesday. Make sure to include statements of ethical principles in your diagrams.

Due Friday

For each stakeholder, submit a clear and concise prose summary and argument diagram of each position that the stakeholder might plausibly give. Include a bibliography of all the sources used.

Between Friday and Tuesday's class (individually at home)

Based on a reflection on all the stakeholder positions you discussed, decide what course of action you think is best. Develop your position by considering 1) all of the relevant ethical issues, 2) how your solution addresses the concerns of the stakeholders, and 3) morally significant short- and long-term consequences.

Tuesday (in class)
Decide what position your group is going to argue for by discussing the issues you considered over the weekend. Work on summarizing the position (and the argument for that position) that your group has chosen.

Thursday (in class)
Review and revise the argument diagrams to represent each of the arguments for the stakeholder positions you submitted last Friday. Create an argument diagram to represent the position that your group has chosen.

Due Friday
The final version of your group's summaries and diagrams for each stakeholder's position, as well as the prose argument and argument diagram for the position your group has chosen.

Appendix B

The Engineering and Science Issues Test

Borenstein, Kirkman, and Swann provide the following as an example of the kind of questions students will encounter in the test.

> Suppose you are planning to buy some real estate for investment purposes. You have come across a parcel of land that is for sale and need to decide whether it is a worthwhile investment. In this example, you are considering five questions about the parcel, and you rate each of them according to their importance in shaping your decision, on a scale of 1 to 5 (1=great importance, 2=much importance, 3=some importance, 4=little importance, 5=no importance).
>
> 1) How close is the parcel to the fringe of suburban development?
> 2) How is the land currently zoned?
> 3) Is the asking price of the parcel comparable to that of similar parcels in the area?
> 4) What is the composition of the topsoil of the parcel?
> 5) Is the current owner of the land a nice person?
>
> Once you have rated the questions you need also to rank them, selecting the four questions you consider to be most important.[35]

Scoring the ESIT

Each question for a given case has been previously identified as concerning either a pre-conventional, a post-conventional, a conventional, or a nonsense issue. First, the scorer must determine "the number of post-conventional points assigned to each student's ranking scores for each dilemma. A post-conventional issue ranked as the first most important issue earns four points. If it ranked as the second most important issue, it earns three points, etc." The post-conventional score (Pscore) is the sum of all the post-conventional points over all six dilemmas.

Second, the scorer calculates "each student's average rating (1–5) on all post-conventional issues and all pre-conventional issues as well as the standard deviation of ratings on all post- and pre-conventional issues together." Then, the "N2score = Pscore − 3* (average rating on post-conventional issues minus the average rating on pre-conventional issues) divided by the standard deviation of ratings on pre- and post-conventional issues."

Notes

1. American Society of Civil Engineers, "Code of Ethics, July 2017."

2. Accreditation Board for Engineering and Technology, "Criteria for Accrediting Engineering Programs, 2018–2019." The way this teaching is to be done is unspecified, so they could offer standalone ethics courses, have faculty teach a kind of "ethics across the curriculum" course, direct students to online resources, or employ some combination of all of these methods.

3. Clarkeburn, Downie, and Matthew, "Impact of an Ethics Programme in a Life Sciences," 66.

4. Schlaefli, Rest, and Thoma, "Does Moral Education Improve Moral Judgement?"

5. See, for example, Schlaefli, Rest, and Thoma, "Does Moral Education Improve Moral Judgement?"; Frisch, "Teaching Nursing Ethics and Promoting Moral Development"; Bebeau and Brabeck, "Integrating Care and Justice Issues"; Self, Wolinsky, and Baldwin, "The Effect of Teaching Medical Ethics"; Penn, "Teaching Ethics: A Direct Approach"; O'Donnell et al., "Changes in Moral Reasoning During Medical School"; Bredemeier and Shields, "Applied Ethics and Moral Reasoning in Sport"; Krawczyk, "Effects on Moral Development"; and Self and Ellison, "Influence on Moral Reasoning Skills."

6. I am grateful to Robert Kirkman for introducing me to this way of teaching.

7. Duffy and Cunningham, "Constructivism"; Savery and Duffy, "Problem-based Learning"; and Torp and Sage, *Problems as Possibilities*. For the benefits of collaborative learning, see Johnson, Johnson, and Stanne, *Cooperative Learning Methods*; Springer, Stanne, and Donovan, *Effects of Small-Group Learning*; and Terenzini et al. "Collaborative Learning vs. Lecture/Discussion."

8. Torp and Sage, *Problems as Possibilities*.

9. Stinson and Milter, "Problem-based Learning in Business Education."

10. Gijselaers, "Connecting Problem-based Practices."

11. Woods, *Problem-based learning*.

12. Hmelo-Silver, "Problem-Based Learning."

13. Strobel and van Barneveld, "When is PBL More Effective?"

14. Hans, "Integrating Active Learning."

15. Donham, Schmeig, and Allen, "The Large and the Small of It."

16. Groh, "Using Problem-based Learning in General Chemistry."

17. Williams, "Introductory Physics: A Problem-based Model."

18. See Duch, Groh, and Allen, "Why Problem-based Learning?"; Torp and Sage, *Problems as Possibilities*; and Hmelo-Silver "Problem-Based Learning."

19. Albanese and Mitchell, "Problem-based Learning" and Vernon and Blake, "Does Problem-based Learning Work?"

20. Denton et al., "Does Problem-based Learning Change Graduate Performance?"

21. Berkson, "Problem-based Learning."; Denton et al. "Does Problem-based Learning Change Graduate Performance?"; and Torp and Sage, *Problems as Possibilities*.

22. See, for example, Boud and Feletti, *The Challenge of Problem-based Learning*.

23. See, for example, Duch et al., *The Power of Problem-Based Learning*, and Amador et al., *The Practice of Problem-Based Learning*.

24. I also often invite a member of these research groups to give a presentation to my students in class about how they have made these decisions.

25. Students gave informed consent for their data to be used, and this study was approved by CMU's internal review board.

26. Borenstein et al., "The Engineering and Science Issues Test."

27. Kohlberg, *The Philosophy of Moral Development*. I want to acknowledge the criticisms that Carol Gilligan (1982) and others have leveled against Kohlberg's theory of moral development. While I am very sympathetic to these criticisms, I do not think they are pertinent here, for three reasons. First, the moral frameworks that the students study and use in solving their problems include ethics of care, as well as utilitarianism and Kantian deontology. Second, the ESIT is, to my knowledge, the only standard test of moral development in engineering and science available. Third, the women in my course did not have significantly different scores on either the pretest or the posttest in this study.

28. Rest and Narvaez, *DIT-2: Defining Issues Test*.

29. Borenstein et al., "The Engineering and Science Issues Test."

30. Borenstein et al., 391.

31. To avoid a conflict of interest, I employed a graduate student, who didn't know which tests were the pretests nor which tests were the posttests, to grade the de-identified tests.

32. Mayhew et al., "Taking the DIT-2 Multiple Times."

33. There are, of course, many issues to consider when relying so heavily on teamwork. Fortunately, engineering students have much practice working in groups for various projects, so only supplemental instruction on group dynamics is needed. There are, however, other problems encountered in group work that makes the students apprehensive. Two of these other problems have traditionally been 1) finding time to meet outside of class and 2) free riders. These problems can be addressed as follows. First, group meeting time is class time, and the work the students need to do individually is done outside of class. This allows the instructor to monitor the group sessions, answer questions that arise, and steer the group in fruitful directions. Second, when the groups turn in their final report, they also

turn in evaluations of the participation of each of the other group members. These two components—seeing the groups working in class and having peer evaluations—alleviate the free rider problem.

34. Adapted from Hudecki, "Can a Genetic Disease Be Cured?"

35. In the actual test there are twelve questions for each case instead of five.

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