Challenges and Opportunities in Ethics Education in Biomedical Engineering

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I. Introduction

The challenges of interdisciplinarity—integrating bioscience, biomedical, and bioengineering knowledge and skills—are well known to biomedical engineering (BME) educators. Undergraduate BME engineering educators face the additional challenge of preparing their students for diverse professional career paths in a wide variety of settings—as engineers in industry, physicians in private or public medical clinics, biomedical researchers in academia, industry or government, and many others. The opportunities opened up by interdisciplinarity and this profusion of career paths are also well known: fresh insights from novel cuts through old problems, techniques ported across disciplines and practices, innovations transferred from laboratory bench to surgeon's suite. The distinctive opportunities for graduates are a function not only of interdisciplinarity and diverse career options, but of the common subject matter and purpose of their work: interventions in life systems for human benefit.

Ethics education for BME undergraduates presents related challenges and opportunities. Across cultures and religions, time and place, individuals care vitally about interventions in life systems. They value highly the potential benefits for human well-being and they greatly fear the potential harms. They may attach ethical significance to interventions—regardless of any benefits or harms—because the subject matter consists of living things. They often disagree with one another about the ethical and social implications of interventions due to differing and inconsistent worldviews. Understanding and addressing these professional, ethical, and social issues will be difficult but integral to the work of BME graduates regardless of the particulars of their career path or work setting. But the particulars of these issues will vary according to profession and workplace: engineers may be chiefly concerned with ethical responsibilities that run to employers, clients, and end-users; physicians may be concerned primarily with responsibilities to patients; and the most salient ethical issues for researchers may center on the use of animal or human subjects in experiments. The BME curriculum is already crowded due to the demands of developing interdisciplinary scientific and technical expertise, and faculty are already stretched to the limit meeting the demands of interdisciplinary instruction. If undergraduate BME ethics demands both in-depth and wide-ranging treatment of these difficult

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issues, how can it find a place in the curriculum? And how can faculty hope to meet the demands of providing a foundational education in ethics spanning three professional domains?

While the challenges are significant, BME undergraduate programs, including the program at Georgia Institute of Technology, have already developed a variety of approaches to integrating ethics instruction into the curriculum. In this paper, we will sketch a proposal for an additional approach.

And, we note, there are not only significant challenges, but significant opportunities for this generation of BME educators and their students. There is the opportunity to introduce future engineering, medical, and research professionals to some of the most compelling, interesting, difficult, worthwhile, and controversial ethical issues of our times while they are engaged in studying a common curriculum. There is the opportunity to develop ethical knowledge and skills that will enable them to exercise leadership in addressing these issues within their own professions and in cooperation with professionals in other domains. Our proposal for an additional approach, and much of the effort already undertaken by BME programs, acknowledge these opportunities as well.

We suggest that the evolution and development of ethics pedagogy for undergraduate BME programs can be modeled as set forth in Figure 1. The rationale for including ethics instruction in the BME curriculum serves as a touchstone for specifying learning objectives that vindicate this rationale. Attaining these learning objectives is not a straightforward exercise since it requires not just teaching, but learning, and educators must hypothesize methods and content that they have reason to believe will be effective in supporting learning. Ultimately, educators must test their hypotheses by implementing them and assessing the results—a crucial final step, but one we do not attempt to address in this paper.

In Part II, we articulate the rationale for incorporating ethics instruction in the undergraduate BME curriculum; we have already alluded to some of the reasons. We then specify a set of learning objectives that would appear to vindicate this rationale and we characterize the methodology and content that might reasonably support attainment of these learning objectives. The remainder of our paper focuses on methods and content: in Part III, we present the results of a survey of selected aspects of ethics instruction in BME programs and describe the approach undertaken at Georgia Institute of Technology to date; and, in Part IV, we conclude with a call for the creation of new problem-based learning modules for ethics instruction developed by interdisciplinary teams, whose members may include faculty, staff, students, and practitioners.

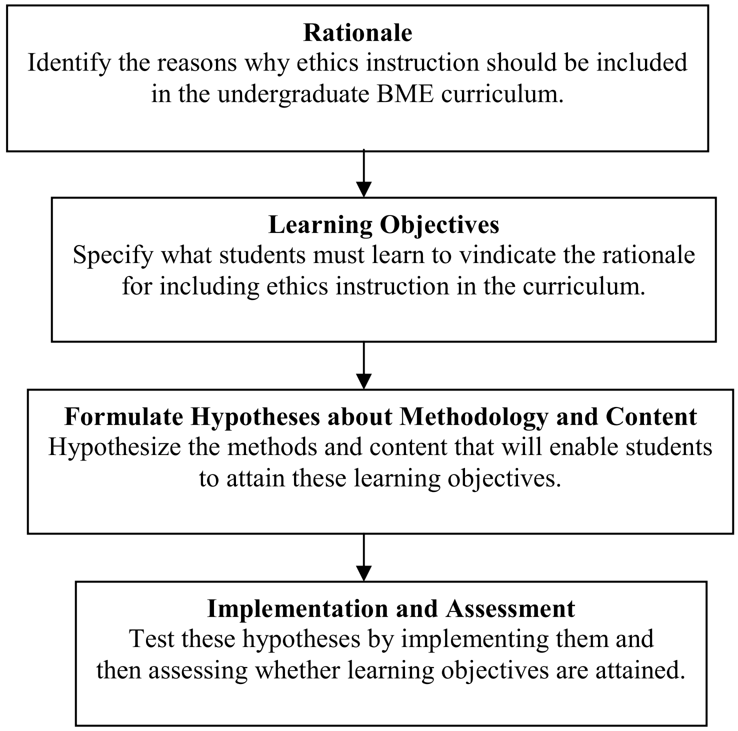

Figure 1. Model of development of ethics pedagogy

II. Rationale, learning objectives, methodology and content

A. Rationale

There have always been good reasons for engineers of all kinds to acquire and apply the knowledge, skills, and professional virtues—honesty, integrity, fidelity, responsibility, and so on—necessary to bring the benefits of engineering to clients, employers, and the public, while safeguarding against doing them harm.[1] Success yields the satisfactions of performing one's art well, making a living, and earning the appreciation and respect of clients, employers, and the public. Failure, on the other hand, may constitute a breach of contract, a violation of statutory or regulatory law with civil or criminal penalties attached, or a tortious act that results in civil liability; the satisfactions of success can be lost in an instant.

There have also always been good reasons for engineers as a profession to support one another in the collective endeavor to ensure that each engineer is equipped to succeed.[1] Engineers can take collective satisfaction in the accomplishments of their profession and the benefits it renders; the failures of fellow professionals, on the other hand, may bring disrepute on all, motivate public regulation as a substitute for public trust in individual judgment and professional self-regulation, and contribute to the unwillingness of clients, employers, or the public to undertake the risks necessary to realize benefits for fear of the worst.

There are ample reasons, then, for undergraduate engineering programs, the Accreditation Board for Engineering and Technology, Inc. (ABET), and professional engineering associations to devote substantial effort to ensuring that future engineers develop the knowledge, skills, and professional virtues requisite to success.[2-4] There are limits to what education can accomplish: ethical behavior ultimately is a matter of individual choice from character, and the character of future professionals is largely the product of influences at work before they entered the undergraduate classroom.[4-7] But there are opportunities to convey the knowledge and skills necessary to ethical conduct and to motivate students to learn; engineering faculty can incorporate ethics instruction in their courses and demonstrate the importance of learning about ethics by teaching the material themselves. And there are opportunities to influence the development of character; faculty can model ethical reasoning and conduct in the classroom and at the bench.[4-10]

Reasons to teach the traditional core of professional ethics persist, but there are compelling reasons to expand ethics instruction well beyond this core. As the power of engineering has grown and its reach has extended into nearly every corner of modern life in the developed world, so have concerns about its ethical and social implications.[11-13] There may be, for example, distributional issues about who will enjoy the benefits and who will bear the risks among national and international communities and between current and future generations. Somewhat different engineering solutions may have profoundly different implications for the allocation of public and private resources, a matter of concern in a world still characterized by scarcity in meeting the basic needs of many. There may be widely held values concerning the environment and sustainability that are separate from health and safety concerns. The twenty-first-century engineer must be aware of and competent to address these sorts of ethical and social issues—and this imposes new demands on educational programs for engineers.[11,12] As ABET recognizes in criterion 3(f), students must understand their "professional *and ethical* responsibility" [emphasis added] and, in criterion 3(c), students must be able to design a project to meet "desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."[2]

BME educational programs face a distinctive set of challenges and opportunities in educating undergraduates both in the traditional core of professional virtues and in the ethical and social implications of their work.[8] This is due, first, to intense and widespread concern with the potential benefits and harms and the ethical significance of interventions in life systems and, second, to the diversity of career paths that their graduates will pursue.

There is heightened interest in realizing the potential benefits and in avoiding the potential harms associated with interventions in life systems. And, with the growing power and success of the professions centered around these interventions, concerns about their broader ethical and social implications have grown as well. Given the pluralism characteristic of modern national and international communities, perspectives on these issues will be diverse and often conflicting. If they are to succeed in their work in the twenty-first-century social and political environment, graduates of BME programs will need to cope with a range of ethical and social issues that will be pressed upon them, from conflicting points of view, by clients, employers, patients, policymakers, advocacy groups, and the public.[7,8,10,13-15]

Because graduates may work for an engineering firm designing biomedical devices, or for a health maintenance organization in clinical practice, or for a university conducting biomedical research, the demands for designing and delivering an adequate foundational undergraduate ethics curriculum are daunting. Each of these professions—BME, medicine, and biomedical research—has a distinct and largely separate history in developing and codifying a traditional core of professional ethics, although there are commonalities across these traditions. Each of these professions faces a distinctive set of ethical and social issues, although, once again, there are commonalities. The challenge and opportunity here is to educate graduates who are competent to address the issues within their own professions as well as those that span the other professional realms.[7,8,16]

In sum, the rationale for including ethics education in the undergraduate BME curriculum includes:

(1) Knowledge and skill in the core of traditional professional ethics are essential to the successful professional practice of BME graduates.
(2) Knowledge and skill in understanding and coping with the ethical and social issues associated with BME, medicine, and biomedical research are also essential to the success of these graduates.
(3) BME graduates will have opportunities to exercise leadership in addressing the intense and often conflicting viewpoints that often are associated with these issues and in addressing those issues that span professional domains.

B. Learning objectives

It follows from this three-part rationale that the learning objectives for ethics instruction will include knowledge and skills concerning both the traditional core of professional ethics as well as broader ethical and social issues, and will include knowledge and skills that pertain to these issues as they arise in BME, medicine, and biomedical research. This knowledge and these skills should enable graduates to choose a course of action that is justified by reference to normative standards and that is practical in the sense that it enables them to cope with the actual choice situations that they will encounter in their future professional lives.

More specifically, students will need to learn the content of significant professional codes, bodies of law, and leading applied ethical theories (e.g. deontological, utilitarian, or virtue-based) that pertain to engineering, medicine, and biomedical research.[3,7,8,17-20] Graduates of BME programs cannot hope to engage in practical reasoning pursuant to normative standards if they have no knowledge of these standards. Professional codes express the collective judgment of practitioners; law expresses the collective judgment of policymakers, pursuant to the influences of the public, interested parties, and experts; and applied ethical theories express the judgment of expert ethicists. The normative standards set forth in these codes, law, and applied ethical theories change over time in response to argument, experience, reflection, new knowledge, and changing circumstances. But professionals can neither justify their current choices nor participate in the ongoing process of revision to these normative standards unless they have knowledge of them.

Bringing these normative standards to bear is not an easy task. The normative standards set forth in a professional code or law may conflict with the normative standards set forth in an applied ethical theory, and any two applied ethical theories likely will conflict at least in part with one another. The normative standards set forth in a code, law, or theory may appear to be internally inconsistent, or may fail to address clearly or in helpful detail the ethical issue at hand. A decision maker may discover that the relevant normative standard conflicts with her personal ethical beliefs. Graduates will require more than "book" knowledge of the contents of selected codes, law, and theories; they will need to develop the practical reasoning skills that professionals are continually called upon to exercise in their work. They will need to develop proficiency in identifying and understanding ethical issues in all their complexity; coping with gaps, uncertainty, and conflicts in normative standards; managing disagreements about the relevant normative standards or their application; and reconciling their personal and professional ethical lives. If they are to exercise leadership in addressing the conflicting views characteristic of a pluralistic world, they will also need to develop the skills required for finding the common ground, forging a compromise, or inventing another solution. If they are to exercise leadership in resolving ethical issues that span professional domains, they will need to develop the skill to work from commonalities across domains to common solutions that address the ethical parts as well as the whole.[5,7,8,10,14,21,22]

In sum, we propose that the learning objectives for undergraduate BME ethics curricula should include:

(1) Knowledge of significant current sources of normative guidance pertaining to professional, ethical, and social issues associated with BME, medicine, and biomedical research.
(2) Problem-solving skills in identifying and understanding professional, ethical, and social issues embedded in real-world scenarios, and in determining how normative standards can be brought to bear to resolve these issues under conditions characterized by uncertainty, disagreement, conflict, and implications that span professional domains.

C. Methodology and content

A great deal of thought and effort has been applied to developing appropriate methods and content to support the attainment of learning objectives that track, in significant part, the objectives we have proposed above. Selected approaches to curricular deployment include a single course or set of courses dedicated exclusively to ethics education, infusion of ethics education across the curriculum, and incorporation of ethics instruction in a one or more existing courses such as a freshman foundational course or a senior design course.[10,18] Instructors may include engineering faculty, engineering practitioners, humanities or social science faculty, or multidisciplinary teams.[8,10,18] Students participating in ethics courses or ethics exercises may be drawn from multiple disciplines.[8,14,15] Pedagogical techniques employed include combinations of problem-based learning[15,18], case-based instruction[7,8,10,14,22], role-playing exercises[22], debates[10,22], class discussion[10,22], group and individual research[10,22], group decision-making exercises[10], and the use of films depicting ethical issues.[14] Course content includes instruction in professional codes of ethics, bodies of law, and applied ethical theories, and exercises in various problem-solving skills such as consensus building.[7,8,10,14,16,18,21,22]

We hypothesize, generally, that the best approach to supporting students in the attainment of our proposed learning objectives will deploy ethics instruction taught by engineering faculty across the curriculum. Ethics instruction should be included early in foundational courses, in selected courses across the curriculum, and in a senior design experience that requires students to work at a high level of sophistication in integrating scientific, technical, and ethical knowledge and skills. We cannot expect students to attain knowledge of relevant normative standards or acquire the complex problem-solving skills required for addressing ethical issues without significant, sustained, and well-planned curricular treatment—as with other components of the BME curriculum. And, as with other components of the curriculum, engineering faculty will be in the best position to lead students to a sophisticated integration of the entire range of knowledge and skills BME graduates will require in their future professional careers—non-engineering faculty, generally, will not possess the breadth and depth of scientific and technical expertise to enable them to do so.

Instructional techniques must focus on the most serious impediment to attainment of these learning objectives: failure of students to engage ethical problems actively. Techniques must help students develop the habit of entering into problems, bringing all of their faculties to bear in the struggle to understand them, seeking out resources and skills that might help them solve them, and developing the judgment that comes with practice under the guidance of educators that will enable them to address these problems with increasing competence. Teaching swimming from the shore is of little benefit to those who one day will need to swim in swift currents. Instructional techniques for BME ethics, if they are to help prepare future professionals to succeed, will simulate as closely as possible the swift currents they will soon encounter.

The content of instruction should include the significant sources of normative standards set forth in professional codes of ethics, bodies of law, and applied ethical theories. These will be of little use, though, in the absence of instruction in the skill-set that professionals, policymakers and lawyers, and ethicists have developed and applied in solving problems that fall within the reach of normative standards in their domains. The application of these skills can be modeled by instructors and examples of the application of these skills can be found in the opinions issued by professional associations of engineers and physicians, the position papers of policymakers and opinions crafted by judges, and the scholarly treatments of current ethical issues by ethicists.

In sum, our three-part hypothesis regarding an apt general methodology and content for attaining the learning objectives we have proposed above is as follows:

(1) Curricular deployment should be throughout the curriculum, with relatively more emphasis in early foundational courses and a capstone senior design course, and instructors should be engineering faculty, with contributions from practitioners and other faculty.
(2) Instructional techniques should be centered on the presentation of realistic, contextualized issues for problem-based learning.
(3) Content should include the normative standards set forth in significant professional codes, law, and applied ethical theories, and problem-solving skills, as developed and applied by professionals, lawmakers, and ethicists, in relating these standards to ethical issues in BME, medicine, and biomedical research.

We next present the results of a December 2004 survey of selected aspects of methodology and content in several bio(medical) engineering programs together with a description of efforts to develop problem-based ethics instruction at Georgia Institute of Technology to date. In Part IV, below, we advance a more specific proposal for the development of a wide-ranging set of comprehensive, problem-based learning modules suitable for instruction by engineering faculty, and we compare the features of this approach to the results of our survey and to our description of the current approach at Georgia Tech.

III. Current status of methodology and content: survey and example

A. Survey of ABET-accredited bio(medical) engineering programs

A web-based survey was devised to shed some light on the pedagogical methods and content of ethics instruction in undergraduate bio(medical) engineering programs. Department chairs for the 32 undergraduate bio(medical) engineering departments with ABET accredited degrees were invited via e-mail to participate in the survey. The chairs were asked to either complete the survey themselves, or to designate that responsibility to a member of their faculty most familiar with their curriculum.

The survey, which had a 66% response rate, and its results are shown in Figure 2. The results show that the majority of the programs responding to the survey incorporate elements of professional and ethics instruction in multiple courses in their curriculum. Whether or not these results can be extrapolated to the 34% of the programs from which no responses were received is unclear. It is possible that a non-response is indicative of a program for which ethics instruction is not considered a high priority within the curriculum.

The survey data reveal that there appears to be relatively good coverage of the issues closer to the traditional core of engineering ethics, such as professional ethics and safety, and relatively less coverage of very important issues that BME faculty are less likely to have expertise in, especially health care costs, individual and public health risks and benefits, and social ethics. Also, there is relatively more coverage of the interested parties at the center of traditional core ethical concerns in engineering, medicine, and research (end-users, patients, research subjects), but relatively less coverage of other interested parties who will be very important to the careers of BME graduates: payers for health care, funders of research, disability and disease communities/advocates. Again, this is likely attributable to lack of faculty expertise in these areas.

Survey Question	Response (%)
1. Your department satisfies Criterion 3(f) primarily by (check only one)	
• Teaching students about professional and ethical responsibility in a single course devoted primarily to that topic	14
• Combining material related to professional and ethical responsibility with other content in a single course in the curriculum (e.g. senior design)	5
• Infusing content pertaining to professional and ethical responsibility in multiple courses in the curriculum	71
• Other (please describe):	10
2. Which of the following professional/ethical concerns are the primary subject of a total of at least three hours of in-class lecture or discussion within in your required curriculum (check all that apply)	
• Individual and public health risks and benefits (e.g. genetic testing, screening for mad cow disease)	33
• Product safety (e.g. FDA safety regulations, good manufacturing practice)	86
• Health care costs (e.g. costs versus benefits, societal costs)	52
• Workplace ethics (e.g. respect, honesty, responsibility, fairness)	71
• Professional ethics (e.g. engineering code of ethics)	86
• Research ethics (e.g. human and animal subjects, integrity of data collection and analysis)	81
• Health care ethics (e.g. responsibility to patients, professional medical standards)	71
• Social ethics (e.g. stem cell research)	33
• Other (please describe):	14
3. In addressing the concerns you checked in #2, identify the interested parties that are included in the content discussed (check all that apply)	
• End users of technologies/devices	90
• Patients	86
• Disability and disease communities/advocates	38
• Human subjects	90
• Animal subjects	71
• Clients	57
• Employers	76
• Co-workers	52
• Fellow professionals	57
• Professional societies and associations	61
• Private funders of research	29
• Public funders of research (e.g. NIH and NSF)	43
• Private health insurance companies	28
• Public health payers (e.g. federal, state and local governments)	24
• Regulators	38
• Society/public	81
• Other (please describe):	10

Figure 2. Survey questions and results

B. The Georgia Tech experience

The Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University has implemented an integrative approach to the ethics education in its undergraduate biomedical engineering degree program. This approach anchors development of ethical reasoning skills in the context of problem solving and design experiences over the 4-year curriculum. It provides multiple opportunities for the students to work on and develop skills and knowledge in a variety of simulated real-world engineering settings where ethical issues must be addressed.

This approach requires that courses throughout the curriculum be identified as venues for ethical reasoning skills development to occur. In the Coulter Department we have selected six courses as venues, as described in Table 1. Separate problem-based learning (PBL) courses are positioned in the first and second years. PBL experiences are incorporated into instructional laboratories associated with third-year systems physiology and biomedical sensors courses. The curriculum culminates with a two-semester senior design course sequence, which is a natural extension of the PBL experience.

Course	**Experience(s)**	**Location within Curriculum**
BMED 1300 Problems in BME I	PBL problems	1st year
BMED 2300 Problems in BME II	PBL problems	2nd year
BMED 3161 Systems Physiology II	lab and design projects	3rd year
BMED 3500 Biomedical Sensors and Instrumentation	design project	3rd year
BMED 4600/4601 Senior Design Project I/II	design project	4th year

Table 1 Courses with integrative ethics

In each course, the need for real-world problems cannot be overstated. Authentic, open-ended problems are needed as contexts and catalysts for the development of ethical reasoning skills. Not only do they help prepare students for the professional practice of engineering but they are also a significant motivator for the students to delve more deeply into the problem-space.[23] Moreover, the use of these skills in the context of a large problem makes them central not peripheral to biomedical engineering problem solving.

Careful selection of PBL problems is necessary to ensure that the experiences allow the students to explore professional and ethical responsibilities and the impact of engineering solutions in a global and societal context. Fortunately, the problem space for the field of biomedical engineering is filled with topics that capture considerable mass media, and therefore student, attention. For example, there have been a number of recently publicized cases of unethical conduct in research involving human subjects. To help our students better understand the ethical issues associated with research involving human subjects, we assign them a PBL problem like that shown in Figure 3. To complete such a problem, every student must complete Institutional Review Board (IRB) training on the basic principles governing the ethical conduct of research involving human subjects. Problems like this are relatively simple for BME faculty to create given that ethics in human subject research is relatively close to the core ethics issues most BME faculty are familiar with.

Only recently have Georgia Tech BME faculty begun to develop problems that address issues related to public health risks and benefits, health care ethics, and societal ethics. An example of such a problem assigned in BMED 1300 *Problems in BME I* is shown in Figure 4. The experience of the faculty who facilitate the groups of students tackling problems like these is that the students generally try to avoid addressing the ethical issues. They would prefer to address only the engineering aspects of the problem and leave the ethical aspects for someone else to worry about. It is a challenge both for the problem designer and the faculty facilitator to insure that the students recognize the importance of addressing ethical issues as part of the engineering problem-solving process.

IN YOUR EAR

Fever measurement has been regarded as a diagnostic tool in routine medical practice for over 130 years. However, body temperature measurements and their interpretation vary, depending on a number of factors. These include the type of thermometer, the measurement site, the age and sex of the subject, and circadian fluctuations in body temperature.

One of the relatively newer techniques for detecting the presence of fever is through the measurement of ear temperature, also known as a tympanic membrane temperature. Devices designed for these measurements are considered fast and easy to use, features considered to be particularly attractive for use on children. However, there have been numerous reports of concerns over the accuracy, reproducibility and repeatability of temperature measurements made with ear thermometers.

Your group is challenged to develop a hypothesis for identifying a factor, other than device malfunction or poor device design, which contributes to one of the ear thermometer's low performance characteristics (i.e., accuracy, reproducibility or repeatability). You will then develop an experimental design to test that hypothesis. Your hypothesis should be formed based on a thorough study of both the physiology behind body temperature measurements and the sensor technology employed in your device. Your experimental study, to be conducted with an ear thermometer provided to you by your facilitator, must be designed to use the number of human subjects necessary to produce statistically significant results. Please note that your experimental protocol must be approved by the Georgia Tech Institutional Review Board prior before beginning your study.

Figure 3. Example PBL problem

IV. Conclusions

If we are correct in our general hypothesis about the methodology and content that are best suited to supporting students in attaining the learning objectives of BME ethics education, then ethics instruction will occupy a significant place in the undergraduate BME curriculum and engineering faculty will invest significant time and effort in teaching a wide-ranging and demanding body of knowledge and skill set. The results of our survey and our description of efforts to date to incorporate ethics instruction into the Georgia Tech BME curriculum suggest that the state of ethics instruction falls somewhat short of this.

As we noted at the outset, the curriculum is crowded and engineering faculty are already stretched to the limit. It will do no good to say that we all should work harder and do more. We should also acknowledge that those who do not accept our proposed rationale and learning objectives will see no need to do so. But for those who share our sense that we should do more, we propose that a division of labor might allow us to design and maintain a curriculum that is adequate to the needs of our twenty-first-century graduates.

It is unrealistic to expect engineering faculty to perform the research, update, and gather materials from multiple disciplinary domains—from the economics and ethics of health insurance to the law and ethics of stem cell research. But we believe that it is realistic to expect engineering faculty to be able to work with problem-based learning modules developed by interdisciplinary teams, whose members may include faculty, staff, students, and practitioners, that maintain and periodically update them. Already, there are a number of sources in texts and online—we recognize and rely on their value. Our proposal is to institutionalize, through grant support as well as cooperative institutional commitments, interdisciplinary teams whose charge is to develop and continually update comprehensive problem-based learning modules as well as periodically organize conferences where skill sets can be demonstrated and critiques and discussion concerning the refinement and development of new modules can transpire. We plan to pursue a beginning to this project and invite partners to join in the effort.

GENETIC PROFILING

Complaint # 983596-A was filed by Dr. John Smith of Twinsburg OH on May 12, 2003 to the Equal Employment Opportunity Commission. Dr. Smith alleges that NanoTech Inc, a small biomedical company based in Cincinnati, OH discriminated against him on the basis of his genetic profile. Partially because of intense public interest and media coverage, a Congressional committee is investigating this issue, and your team has been called in to testify before Congress as scientific experts on the topic.

The details are as follows: Dr. Smith was let go two weeks after starting as the research director of clinical applications. These two weeks were within the 4 week probationary period made explicit during the interview process. The letter conveying this news to Dr. Smith explicitly stated that he was being let go because genetic analysis on his saliva swab (done shortly after he joined the company) revealed that he had a susceptible serotonin transporter gene ('s/s genotype') that had been identified as responsible for increasing the probability that one might develop Clinical Depression or be non-responsive to anti-depressant therapy. At the time, Dr. Smith had no episodes of depression in his medical history. However, the company stated that this result would significantly impact the company's insurance premiums.

Based on the most current research, you are to testify on the state of the science involved in predicting future disease, specifically depression and associated diseases. Importantly, your recommendations need to be mindful of a variety of stakeholders including individual citizens and employees, employers, insurance companies and society at large.

Specifically, you need to address the following:

- The protocols generally followed in genetic testing, their reliability and accuracy.
- Your recommendation to the Congressional committee from this specific case perspective on the validity of the science behind Nanotech's decision.
- Whether this is a valid case of risk-assessment, or whether it is akin to discrimination on the basis of race, gender or disability, which is explicitly forbidden by law. Effectively, should the Congress enact laws relating to genetic profiling?

Your recommendations should be informed by biomedical science and biomedical ethics.

Figure 4. Example PBL problem

V. Summary

We have asserted that, while the reasons for including the traditional core of ethics instruction in the bio(medical) engineering curriculum persist, there are additional reasons, distinctive to the future careers of bio(medical) engineering graduates, why it is important to face the challenges and seize the opportunities for incorporating treatment of ethical and social issues as well. The learning objectives and our general hypothesis about the methodology and content that can support attainment of these objectives lead to our specific proposal for an ongoing effort to develop and update a comprehensive set of sophisticated, interdisciplinary, problem-based learning modules that can be integrated into courses throughout the bio(medical) engineering curriculum and taught by engineering faculty.

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