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Ethical and Professional Training of Biomedical Engineers*

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Where once ethical concerns in biomedical engineering coursework involved primarily the effects of technology on medicine and health care distribution, several factors currently affect the presentation of ethical material to biomedical engineers. These include the maturation of the field as an ABET (Accreditation Board for Engineering and Technology) accreditable discipline, with the commitment for instruction in ethics and increasing student and faculty concerns over ethical misconduct relating to the profession. This paper reviews ethics instruction at Vanderbilt University, relating past history and current societal expectations to the current expression of ethical concerns in design and design seminars and in a specific course in ethics.

Keywords: ethics; biomedical engineering; technology; design; syllabus

INTRODUCTION

> A man's ethical behavior should be based effectually on sympathy, education, and social ties; no religious basis is necessary. Man would indeed be in a poor way if he had to be restrained by fear of punishment and hope of reward after death.
>
> Albert Einstein (1879–1955)

> . . . I . . . present each new employee with a Medtronic medallion . . .I'm mindful not only of that medallion, but also of the mission it symbolizes. The first and most important tenet of that mission reads, 'To contribute to human welfare by application of biomedical engineering in the research, design, manufacture, and sale of instruments or appliances that alleviate pain, restore health, and extend life.'
>
> Earl Bakken, Medtronic founder (1924–)

Rationale and objectives of this paper

As one of the disciplines considered to be an outgrowth of Biological or Biosystems Engineering, Biomedical Engineering is filling a unique niche in the application of science and engineering technology to problems in medicine and biology. As such, it inherits the potential for ethical studies that are relevant to both engineering and medicine. The objective of this paper is to discuss the past and present stress on ethics in a current biomedical engineering program.

Definition of biomedical engineering

Biomedical engineering is one of the newest and fastest-growing engineering professions. A widely-used simple definition of biomedical engineering is 'the application of engineering tools and analysis to problems in medicine.'

The Whitaker Foundation defines biomedical engineering more broadly, as follows:

> Biomedical engineering is a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice. It includes:
>
> 1. The acquisition of new knowledge and understanding of living systems through the innovative and substantive application of experimental and analytical techniques based on the engineering sciences.
> 2. The development of new devices, algorithms, processes and systems that advance biology and medicine and improve medical practice and health care delivery.
>
> As used by the foundation, the term 'biomedical engineering research' is thus defined in a broad sense: It includes not only the relevant applications of engineering to medicine but also to the basic life sciences [1].

The working definition of bioengineering used by the U.S. National Institutes of Health is:

> Bioengineering integrates physical, chemical, or mathematical sciences and engineering principles for the study of biology, medicine, behavior, or health. It advances fundamental concepts, creates knowledge for the molecular to the organ systems levels, and develops innovative biologics, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health [2].

The Whitaker Foundation's definition of biomedical engineering thus coincides closely with the NIH definition of bioengineering, including applications in biological sciences. Excluded from this definition are applications in agricultural and environmental engineering, reflected in programs

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such as the Departments of Bioengineering at Oregon State University [3] and Purdue University [4]. Our discussion likewise largely excludes these areas.

HISTORICAL INFLUENCES ON ETHICAL AND PROFESSIONAL STANDARDS IN BIOMEDICAL ENGINEERING

Development of an active role in ethics for the biomedical engineer

Aspects of the practice of biomedical ethics date back to the time of Hippocrates (i.e., the exhortation of the medical practitioner to 'do no harm'). However, the science of biomedical ethics and its application to biomedical engineering practice have several more modern impetuses, some of them negative.

1. The advent of modern technology has been accompanied by skepticism and a stream of criticism. Much of it is focused on the engineer. In the words of Nietzsche: 'Even using the yardstick of the ancient Greeks, our whole modern existence is nothing but *hubris* and godlessness. . . . *Hubris* today characterizes our whole attitude towards nature, our rape of nature with the help of machines and the completely unscrupulous inventiveness of technicians and engineers [5].' In contexts of limited finances and uneven distribution of resources, the biomedical engineer is sometimes portrayed as a contributor to the problems through her/his participation in the development of high-cost new technology.
2. The atrocities of so-called medical experimentation in exploitative situations such as the actions of physicians of the Third Reich led to the formulation of documents such as the Nuremberg Code and the Treaty of Helsinki, defining terms under which experiments involving human and animal subjects should be conducted. Principles of conduct of human studies under which defendants in the Nuremberg Trials were judged (retroactively) include: informed consent; risk and benefit (equipoise); subject can terminate her/his involvement; experiment should be based upon prior animal studies; only scientifically qualified individuals should conduct human experimentation; physical and mental suffering and injury should be avoided; and there should be no expectation that death or disabling injury will occur from the experiment.
3. The conduct of medical and clinical studies in which inappropriate treatment was given or treatment withheld, risks and benefits of protocols were explained inadequately or not at all, or the inclusion into human studies of subjects who were not asked or in some cases not able to give informed consent in the U.S. led to the formulation of the Belmont Report as a basis of conduct of such future studies [6]. Three principles of conduct of human studies that are stated in this report are: beneficence, justice, and respect for persons.
4. Instances of fraud in published reports of biomedical research and a perceived hesitance to implicate coauthors, laboratory directors and institutional officials in many such instances has led to intensified vigilance to minimize such occurrences on the part of governmental agencies, universities and research laboratories, the publishing industry and professional societies [7].
5. Widely reported and publicized egregious business practices of the recent past have resulted in the manipulation of the market and of legal and public policy for personal or company gain. There is a corporate and public awareness that such practices are in violation of common principles of ethical behavior. As a result, legal standards have been clarified and strengthened and professional societies and organizations have elucidated and in some cases enforced standards of personal conduct.
6. Advances in biotechnology have presented ethical dilemmas. According to the Biotechnology Industry Organization [8], a working definition of biotechnology is 'the use of biological (cellular and biomolecular) processes to solve problems or make useful products.' The two biotechnology dilemmas that have received the most widespread attention and created much scientific, economic and political controversy are the advent of genetically modified food (GMF, [9]) and the successful completion of the Human Genome Project, leading to the ethical dilemmas of genomic and proteomic science, particularly embryonic stem cell research [10]. Although GMF is within the purview of agricultural engineering, normally considered a separate discipline from biomedical engineering (see above), the challenges of the stem cell research dilemma have profound effects on the science and practice of biomedical engineering. One of the greatest emerging pressures is in the area of so-called biologic devices, implantables that include biologically active materials.

These and similar developments in other fields of engineering have created a call for engineers to take a more active role in the formulation of public policy. 'Ethical responsibility . . . involves more than leading a decent, honest, truthful life. . . . And it involves something much more than making wise choices when such choices suddenly, unexpectedly present themselves. Our moral obligations must . . . include a willingness to engage others in the difficult work of defining the crucial choices that confront technological society . . . [11].'

ABET program accreditation

Most engineering programs in the US aspire to be accredited, which means that the accrediting body, the Accreditation Board for Engineering and Technology (ABET), inspects the program and certifies that the graduates of the program have met a certain standard in terms of course and topic coverage and demonstrated competencies. The inspector for a given curriculum is typically an educator from the same area as the curriculum, or a member of industry working in the area of competency of the graduates. Inspectors are nominated to, and are approved initially by, the representative professional body for that curriculum. The Biomedical Engineering Society (BMES) is the lead society for inspections of biomedical engineering programs. Inspectors come from both industry and academia. The coordinator of campus visits, when more than one program is under review, is typically a 'seasoned' reviewer who may have competency in areas not even being reviewed.

ABET [12] requires that 'Engineering programs must demonstrate that their graduates have (amongst other items) . . .' an understanding of professional and ethical responsibility' (Criterion 3). They further stress that 'Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political.' (Criterion 4)

Inclusion of ethics competency as a component of engineering education has two implications. One is that the topics of ethics, social and political, health and safety, etc. nominally incorporated in codes of ethics for the various professions and written law as applied to the practice of professions, must be covered in coursework leading up to the degree requiring accreditation (generally the BS degree). A second implication is that part of this coverage can be done in the senior design course, but it does not preclude its being covered in other coursework.

A recent overview of practices in ethics education in engineering showed an increased awareness throughout the engineering education community of the need for formal instruction in ethics [13]. Two primary factors were identified: social issues of the kind illustrated above for biomedical engineering, and the growing emphasis by ABET on contemporary issues and standards of ethical conduct in engineering education. According to the overview, in 1999 70 percent of accredited programs in all engineering disciplines had course requirement in ethics. The key concept to be included in such courses was professional responsibility, defined as moral responsibility based on an individual's special knowledge. Typical concerns in existing courses were: conflicts of interest, integrity of data, whistle-blowing, loyalty, accountability, giving credit where due, trade secrets, gift giving and bribes.

In our department, this material is covered in the mandatory senior design course and seminar, and may also be opted for in a new engineering ethics course 'Biomedical Engineering Ethics.' The first two are taught by author King, the latter by author Collins. The coverage of each of these courses will be discussed below.

BIOMEDICAL ENGINEERING ETHICS INSTRUCTION AT VANDERBILT UNIVERSITY

History of ethics courses in biomedical engineering at Vanderbilt

Ph.D. degrees in Biomedical Engineering were first awarded in the U.S. in 1960; undergraduate degrees were first awarded in 1965 [14]. Only about 18 programs were extant in 1975 when one of the first ethics-related courses in biomedical engineering was offered at Vanderbilt by author King. A perusal of the course outline (see Appendix I) shows topics of interest at the time: the history of medicine, concerns about health care distribution and costs, right to life, euthanasia, and ethics. The course was mainly aimed at the technology aspects of engineering's interface with medicine, as much of the course material was novel at the time. Guest speakers, several from the medical school (including one ethicist) gave much credence to the course. It is worth noting that no professional responsibilities on the part of engineers were covered.

At the time, this course was very popular, having as many as 65 students in the class (normal class sizes were in the 20's at the time). A sabbatical on the part of the author and a change in deans, and thus a change in emphasis on the part of the school, spelled the end of this class.

More recently, author Collins offered an elective course 'Ethics and Practice in Biomedical Engineering' to 53 upper-division undergraduates in spring 2004. A syllabus of that course is included in Appendix II. A more detailed discussion will follow the design discussion below.

Engineering senior design seminar [15]

A senior design seminar was instituted in 2003 at Vanderbilt. It pulled material taught separately in the Biomedical Engineering, Mechanical Engineering, Electrical Engineering, and Computer Engineering design classes into a common design class and seminar format. The credit hours in design classes in Biomedical and Mechanical Engineering departments were decreased by one in order to accommodate the joint seminar without adding additional credit requirements for graduation.

The catalog description of the senior design seminar reads: 'Elements of professional engineering practice. Professionalism, licensing, ethics and ethical issues, intellectual property, contracts, liability, risk, reliability and safety, interdisciplinary teams and team tools, codes, standards, professional organizations, careers, entrepreneurship, human factors, and industrial design. Prerequisite: senior standing.'

The reason for offering this course was to collect those design-related issues that are common to many, if not all, engineering disciplines so as to focus our collective best resources from the school on senior design students in this class. This course is meant to assist our students in thinking about engineering design in an interdisciplinary way and provide a node from which interdisciplinary activities can evolve. It is perceived as more efficient to organize common presentations by university resources such as career planning, safety and environment, intellectual property and technology transfer into a common meeting involving all relevant program students. Another fundamental reason for offering the course is to bring multiple senior design faculty together so as to optimize design, teaching and execution of our senior design courses. The seminar was also used as a platform to assist in the generation of interdisciplinary design teams. Many design issues are not grounded in individual disciplines but are instead engineering issues that are better and more efficiently addressed in a collective effort.

The course satisfies many of the required ABET topics, with one-hour lectures on: safe design, reliability, ethics, economics, liability, manufacturing, contracts, safety issues in the workplace, intellectual property, and career planning. In the first year, the course grade was made dependent on attendance and a term paper.

One hundred and thirty-six students were registered for the first offering. Term paper topics were allowed on 12 of the scheduled 15 lectures. Forty-six of the attendees selected the lecture topic of author Collins, titled 'Ethics in Engineering' as a basis for their term papers [16]. Dr. Collins's lecture included the following topics: Fundamentals of ethics, ethics in engineering, codes of ethics (examples), examples of ethical dilemmas, and a class exercise.

A list of their term paper titles is given in Appendix III. Thirteen students elected to title their papers 'Ethics in Engineering,' several writing a generic coverage of the topic. Many students pursued related items, extending their knowledge of the relationship of ethics and engineering via this exercise. The best paper covered the topic 'Codes of engineering ethics: Protecting the welfare of the public.' The student's conclusion was that by maintaining an ethical focus engineers can maintain their duty as ethical stewards of present and future technologies. Perhaps the most unusual paper was on 'The ethics of weapons research and development,' which looked at the historical contexts and subsequent effects of weapons research.

Most students' papers were reasonably researched and demonstrated an interest in delving further into an area of ethics that had not been covered in lecture. Many students' papers did not discuss the relationship between ethics as laid out by professional societies and laws mandating ethical conduct as promulgated by state licensing agencies. We will attempt to remedy this deficiency with a discussion as the structure of ethics per se, from personal beliefs to their codification in laws.

Biomedical Engineering Senior Design at Vanderbilt [17]

The senior design course at Vanderbilt has been taught since 1991 to senior biomedical engineering students. It became a two-semester sequence in 1996.

The catalog description for the course reads: 'BE 272-273 Design of Biomedical Engineering Devices and Systems I and II: An integration of the engineering and life science backgrounds of senior biomedical engineering students through the presentation of design principles for medical devices and systems. **272:** Design principles and case examples for biomedical electronics, mechanical, chemical, and computing systems. **273:** A full semester design project is required. Evaluation via periodic oral and written presentations and a final written and poster report.'

The lecture portion of this course (Fall term) has been abbreviated because a number of topics once covered in lectures here were subsumed by the above design seminar lecture series. Ethics and ethical standards are, however, still covered in this class, especially as they apply to the profession of biomedical engineering.

The course textbook [18] has one chapter titled 'Professional Issues.' It discusses BME (and Bioengineering) related professional societies, standards setting groups, licensure, codes of ethics (NSPE, IEEE, etc.), consulting and forensics, and continuing education. A few ethics-related homework questions are appended at the chapter's end.

The regulatory effect of the FDA is evident throughout the text, with specific chapters relating to: the FDA (history and device classification and regulation), safety engineering, premarket testing and validation, system testing, quality control, and good manufacturing practice. Animal and human testing issues are covered in a chapter on biomaterials and materials selection, premarket testing (drug development and clinical trials), and in the history of the FDA chapter. *The Jungle*, by Upton Sinclair, and a discussion of the very spotty early history of food and drug regulation in the U.S., are covered in the chapter on the FDA. NIH requirements for use of humans in experimentation are also covered under discussions on informed consent.

Students are further required, in the conduct of their design project, to address the ethics of the device or process on which they have worked. They are specifically asked if their device or process excludes anyone, and if there has been ethical treatment of subjects (human or animal).

For all projects to which the concept applies, each student team must also run a designsafe [19] analysis of their project. This is to ensure that the students have considered the health and safety aspects of their work.

Biomedical engineering ethics

An undergraduate elective course 'Ethics and Practice in Biomedical Engineering,' now titled 'Biomedical Engineering Ethics,' was offered for the first time in spring 2004 to 53 undergraduates. Course goals included the development of perception, competency, tentativeness and discrimination in approaching ethical situations. Principles of biomedical ethical behavior beneficence, non-maleficence, respect for autonomy and justice are illustrated (or not) in a series of films (*Miss Evers' Boys*, *And the Band Played On*, *The Insider*, *Deadly Deception*, *Cracking the Code of Life*, *Bioterror*, *Something the Lord Made*) and a broad array of cases of clinical studies, business ethics, ethics in scientific research and mentoring of young biomedical engineers. In this course, students come to realize that the science and profession of biomedical ethics has largely developed from past mistakes. Principles of literary criticism are introduced in a discussion of media as dialogue. Cultural filters through which readers/listeners encounter ethical situations are examined and responsibilities to respond appropriately are emphasized. Another way of expressing this course feature is that readers are taught and encouraged to 'listen against the film' or 'read against the text.'

The learning principles and methodologies of the course are centered on the Legacy learning cycle [20] in accordance with the learning principles addressed in *How People Learn* [21]. The HPL model integrates four primary learning foci (Fig. 1). Knowledge centeredness refers to the new information that students will encounter in the course. The course instructor has the primary responsibility in this area. Accurate and adequate amounts of information must be made available to students in a way that stimulates their interest and builds on information and ideas that they bring to the learning experience. Learner centeredness represents the focus on the learner and the learning process. Learners are encouraged and led to learn with understanding, not just to memorize facts and concepts. Students come from a wide variety of educational and moral/ethical backgrounds. Expression of divergent views can provide new information and increased understanding for other students, and also provide a basis for the third focus, that of assessment, both formative (helping the learner to evaluate his/her own progress) and summative (allowing the instructor to evaluate the learner's progress). The fourth focus of the learning method is that of community. The learning environment is a community in which learning is optimized through exchange and refinement of ideas. The ideas themselves also represent personal and professional practice in the community. Students appreciate the focus of the course on practical and creative aspects of engineering practice, in accord with ABET accreditation criteria.

A special section of this course is devoted to the discussion of codes of ethics: the Code of Nuremberg, the Belmont Report, the Treaty of Helsinki, and various engineering codes of ethics. Of particular interest in the latter regard is the emergence of the Code of Ethics of the National Society of Professional Engineers [22]. This organization and its code were actually predated by professional organizations and codes of engineering in several states. The statement of the fundamental canons of the NSPE Code of Ethics is as follows:

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Author Collins is chair of the Ethics Committee of the Biomedical Engineering Society. In February 2004, the BMES membership ratified the BMES Code of Ethics (Appendix IV). Areas of conduct covered by the Code are: professional, health care, research, and training or mentoring. The code is aspirational (voluntary) and not punitive in intent. This code is discussed in detail in the Ethics course. Examples and case studies illustrating facets of the code are also studied.

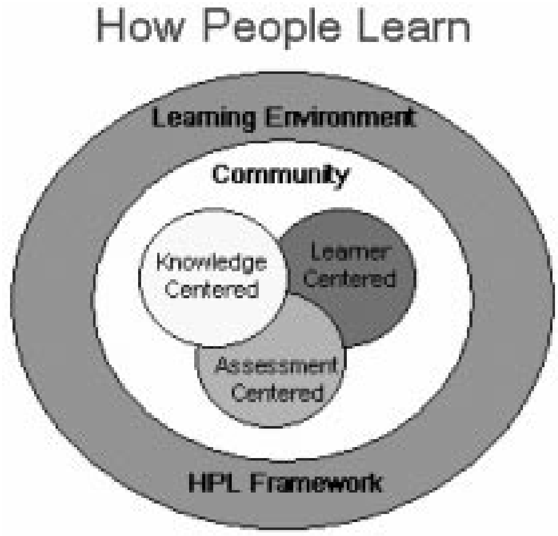

Fig. 1. HPL model: Student learning environment.

SUMMARY

The profession of biomedical engineering is rapidly developing and is influential in the eyes of its members, of sister professions, and of the public. Standards of ethical and professional conduct have been implicit and in some cases have been explicit in the practice of engineering for many years. Recently, societal and professional factors have resulted in the development of specific ethics and practice instruction in biomedical engineering programs such as the Vanderbilt University program described in this paper, and in the formalization of codes of ethics in various engineering societies, including the Biomedical Engineering Society.

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APPENDIX I

Tentative course outline BE 110: Technology and Medicine, Spring 1975

1. Introduction, Course Outline, Responsibilities
2. Hospitals: Aims, Goals, Structure*
3. A Brief History of Medicine
4. A Brief History of Engineering*
5. Biomedical Engineering
6. Clinical Engineering*
7. Technology Assessment*
8. Medical Ethics*
9. The Right to Live*
10. Kidney; Natural, Artificial
11. Kidney: Transplantation*
12. Kidney: Ethics*
13. Heart: Basics, Instrumentation
14. Heart: Pacemakers, Transplants, Ethics*

15. Exam
16. The Right to Life/Health*
17. The Present Health Care System
18. Improving Delivery
19. The Use of Emergency Wards*
20. Health Care Distribution
21. Pre-Paid Care
22. Kaiser-Permante
23. Swedish/English Examples
24. Clinics and Salary Supplements*
25. Multiphasic Screening
26. HMOs*
27. PSROs
28. Exam
29. Genetic Counseling/Engineering
30. Post-Natal Survival—Technology
31. Problems of Youth
32. Environmental Effects on Health*
33. Environmental Effects on Health*
34. Cancer—Detection
35. Cancer—Therapy, Counseling*
36. Euthanasia
37. Aging and Technology*
38. Rehabilitation Engineering*
39. The Future of Technology and Medicine
40. Exam
41. Student Reports
42. Student Reports

*Indicates probable guest speaker

APPENDIX II

Ethics and Practice in Biomedical Engineering course syllabus, Spring 2004

January 15—Overview of syllabus.

January 20—In-class video *Miss Evers' Boys*; Introduction to the Tuskegee study and a brief history before viewing the movie; Pre-questionnaire administered before viewing the movie.

January 22—In-class discussion of *Miss Evers' Boys*; discussion of concept of common morality; mapping Belmont Code principles onto ethical principles in text.

January 27—Discussion of media as dialogue (cultural filters through which reader/listener views, responsibility of reader to respond appropriately); presentations on IRB and Vanderbilt radioactive iron study by guest panel.

January 29—Discussions of radioactive iron study and Taxol class action settlement.

February 3—Presentation of elements of critical theory as introduction to biomedical ethics approaches; application of critical theory to ARDS, Tuskegee, iron studies (principle of tentativity).

February 5—Further examination of Taxol case study.

February 10—Class presentation by Dr. Larry Churchill, Vanderbilt medical ethicist (Principles of ethical analysis applied to two case studies).

February 12—Overview of Nuremberg trials and introduction to Website; mapping Nuremberg Code onto ethical principles in text.

February 17—Movie *The Insider* (Introduction to business and professional ethics).

February 19—Discussion of ethical issues in *The Insider.*

February 24—Presentation on business ethics by Dr. Terry Frisby.

February 26—In-class test.

March 2—Begin to view *Cracking the Code of Life*; discussion of scientific, economic, personal ethical issues.

March 4—Continuation of *Cracking the Code of Life* and discussion of issues.

March 16—Continuation of *Cracking the Code of Life* and discussion of issues.

March 18—Case study—genetically modified food.

March 23—The Challenger disaster and professional responsibility.

March 25—Discussion of professional responsibilities and analysis of Florman essay 'Conscience, Error and Responsibility.'

March 30—Movie *Erin Brockovich*.
April 1—Presentation of BMES and other engineering codes of ethics.
April 6—Movie: *A Right to Die?* The Dax Cowart Case.
April 8—Discussion of The Dax Cowart Case.
April 13—The John Darsee case and research ethics.
April 15—Ethical responsibilities in mentoring of others.
April 20—Final project presentations.
April 22—Final project presentations.
April 27—Final project presentations.

APPENDIX III

Unique titles of ethics-related term papers, Design Seminar, 2003
Titles are followed by number of majors writing under that title: Number of ethics papers total: 46.

Ethics in Engineering (6 BME, 5 ME, 2 EECE)
Ethics (5 BME)
No title (4 BME, 1 ME)
Engineering Ethics (2 ME, 1 ME)
Ethics and Engineering (1 BME)
Ethical Considerations in the Engineering Profession (1 BME)
Ethics of Medical Testing on Human Subjects (1 BME)
Impact of Advanced Technology on Ethics (1 EECE)
The Importance of Ethics in Engineering (1 ME)
The Ethics of Weapons Research and Development (1 ME)
An Engineer's Ethics (1 ME)
Navigating Ethical Dilemmas (1 ME)
Ethics: To who and what are we responsible? (1 ME)
Ethical Practice in Engineering (1 BME)
Humans in Clinical Research Trials: An Ethical Dilemma (1 BME)
The Bioethics of Genetics (1 BME)
The Goal and Duty Based Morality Approaches for Evaluation of Ethicality of Human Experimentation (1 BME)
Ethics in Engineering: Stem Cell Research. (1 BME)
Ethics in Engineering: The Developing Importance of Ethics in Biomedical Research (1 BME)
The Effect of Ethics Applied to the Global Relationships Environment (1 BME)
Ethics in Biomedical Engineering (1 BME)
Bioethics: A Product of the tragedy surrounding the Tuskegee Study. (1 BME)
Ethics: Don't Engineer Without It. (1 EECE)
Codes of Engineering Ethics: Protecting the Welfare of the Public (1 BME)
Engineering Ethics: How do we know the correct answer? (1 BME)
Engineering and Professional Ethics (1 BME)

APPENDIX IV

Biomedical Engineering Society Code of Ethics
Biomedical engineering is a learned profession that combines expertise and responsibilities in engineering, science, technology, and medicine. Mindful that public health and welfare are paramount considerations in each of these areas, the Society identifies in this Code principles of ethical conduct in professional practice, health care, research, and training. This Code reflects voluntary standards of professional and personal practice recommended for biomedical engineers.

Biomedical engineering professional obligations
Biomedical engineers in the fulfillment of their professional engineering duties shall:
1. Use their knowledge, skills, and abilities to enhance the safety, health, and welfare of the public.
2. Strive by action, example, and influence to increase the competence, prestige, and honor of the biomedical engineering profession.

Biomedical engineering health care obligations
Biomedical engineers involved in health care activities shall:

1. Regard responsibility toward and rights of patients, including those of confidentiality and privacy, as a primary concern.
2. Consider the broader consequences of their work in regard to cost, availability, and delivery of health care.

Biomedical engineering research obligations
Biomedical engineers involved in research shall:
1. Comply fully with legal, ethical, institutional, governmental, and other applicable research guidelines, respecting the rights of and exercising the responsibilities to human and animal subjects, colleagues, the scientific community and the general public.
2. Publish and/or present properly credited results of research accurately and clearly.

Biomedical engineering training obligations
Biomedical engineers entrusted with the responsibilities of training others shall:
1. Honor the responsibility not only to train biomedical engineering students in proper professional conduct in performing research and publishing results, but also to model such conduct before them.
2. Keep training methods and content free from inappropriate influence of special interests.

Paul H. King received his Ph.D. in Mechanical Engineering from Vanderbilt University in 1968 and became a founding member of the newly formed Biomedical Engineering Department that same year. He is currently Associate Professor of Biomedical Engineering and Mechanical Engineering at Vanderbilt. He has worked in numerous clinical environments, including anesthesiology, orthopedics, cardiology, nuclear medicine, kidney dialysis, and metabolism research. He is currently concentrating on teaching and researching design in biomedical engineering.

Jerry C. Collins received his Ph.D. in Biomedical and Electrical Engineering from Duke University and post-doctoral training at Vanderbilt University. Dr. Collins is currently Research Associate Professor of Biomedical Engineering at Vanderbilt. He has more than twenty years' experience in clinical research in cardiovascular surgery, clinical nutrition, and clinical research centers. Major interests include physiological systems identification and modeling, and engineering and ethics education. Dr. Collins is an officer in several state and national professional development groups and is chair of the Ethics Committee of the Biomedical Engineering Society.