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BMES BIOMEDICAL ENGINEERING SOCIETY

*Teaching Tips*

# Justice, Equity, Diversity, and Inclusion Curriculum Within an Introductory Bioengineering Course

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**Abstract**—Curriculum initiatives that provide the societal context of engineering practice can contribute to justice, equity, diversity, and inclusion (JEDI) within the profession, as well as within the communities served by engineers. JEDI curriculum can foster diversity and inclusion by acknowledging and addressing social justice issues, providing a safe and inclusive space for students' voices to be heard, and advancing a productive dialogue within their institution of higher learning. Furthermore, such curriculum initiatives can empower students with the theoretical frameworks, analytical tools, and knowledge base to recognize and address ethical challenges and opportunities related to justice, equity, diversity, and inclusion in their field. This Teaching Tips paper offers a description of a pilot program to incorporate JEDI material within a core bioengineering course modeled on evidence-based curriculum programs to embed ethics within technical courses. The author and collaborators sought to achieve two aims with the JEDI-focused material: (1) for students to learn how justice, equity, diversity, and inclusion intersect with bioengineering practice through an interdisciplinary lens of history, philosophy, sociology and anthropology which provide strong scholarly frameworks and theoretical foundations and (2) for students to participate in and foster an inclusive environment within their own educational institution through effectively communicating about these topics with each other. At the conclusion of the semester, a student survey indicated an overwhelmingly positive reception of the material. This paper will discuss the interdisciplinary curriculum development initiative, how the learning objectives were addressed by the specific lesson plans, and challenges to be addressed to create a sustainable educational model for the program.

**Keywords**—Inclusive teaching, Engineering education, Engineering ethics, Ethics across the curriculum, Diversity, Inclusion.

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## CHALLENGE STATEMENT

Curriculum initiatives that provide the societal context of biomedical engineering practice can contribute to justice, equity, diversity, and inclusion (JEDI) within the profession, as well as within the communities served by biomedical engineers.[4,19,43] JEDI curriculum can foster diversity and inclusion among engineering students by acknowledging and addressing social justice issues, providing a safe and inclusive space for students' voices to be heard, and advancing a productive dialogue within their institution of higher learning.[11,31,33,41,44,47] For example, as Busch-Vishniac and Jarosz discuss, several studies have demonstrated that connecting the technical content of engineering curricula with issues of social relevance, diversity, and multiculturalism can improve the gender, ethnic, and racial diversity of students electing and, importantly, retaining an engineering major.[11,21,34,36,37,56] Furthermore, such curriculum initiatives can empower students with the theoretical frameworks, analytical tools, and knowledge base to recognize and address ethical challenges and opportunities related to justice, equity, diversity, and inclusion among our broader society as they intersect with engineering practice.[16]

This Teaching Tips paper offers a description of a pilot program to incorporate JEDI material within a core bioengineering course modeled on evidence-based curriculum programs to embed ethics within technical courses.[22,38] We designed our initiative following the pedagogical approach of "ethics across the curriculum" in which interdisciplinary scholars develop ethics modules within core engineering courses.[22,38] This pedagogical method of embedding ethics content



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within technical courses, in addition to standalone engineering ethics courses, offers several benefits. First, as students learn new technical skills, they simultaneously appreciate the professional responsibilities of engineers.[8,12] This allows the students to consider the societal context of their work throughout their training, rather than considering ethical responsibility as a separate domain.[13,15] The goal is to embed ethical considerations, including JEDI-focused considerations, as part of the design process.[49] Second, the embedded ethics approach allows for discipline-specific ethical considerations to be explored in-depth in tandem with the relevant technical content.[14,50] For example, within a bioengineering program, as students learn about genetic engineering technologies, they can also be provided with frameworks to understand profound societal implications as well as tools to engage in inclusive public discourse with diverse audiences.

## NOVEL INITIATIVE

As part of a pilot program to incorporate ethics content within core engineering courses, the author in collaboration with a teaching assistant developed a series of ethics modules for the first-year level course Introduction to Bioengineering, offered by the Department of Bioengineering at the University of Pennsylvania. The ethics content, including JEDI-focused modules, was piloted during the Fall 2020 semester, which was held virtually due to COVID-19 protocols. The instructor of the course was the Department of Bioengineering's Undergraduate Chair. The author is an historian and sociologist of technology and science and collaborated with an undergraduate teaching assistant with training in philosophy and cognitive science. The course had an enrollment of 69 first-year students.

The Introduction to Bioengineering course was designed to introduce new Bioengineering majors to the breadth of the field through eight technical modules which reflected the areas of concentration within the curriculum: (1) Therapeutics, Drug Delivery, and Nanotechnology; (2) Systems and Synthetic Biology; (3) Multiscale Biomechanics; (4) Neuroengineering; (5) Cellular/Tissue Engineering and Biomaterials; (6) Biomedical Devices; (7) Biomedical Data Science and Computational Medicine; and (8) Biomedical Imaging and Radiation Physics. Introductory lectures were presented on each of these topics by the bioengineering course instructor and other department faculty, representing their areas of expertise. Additionally, students were taught skills in data analysis, image analysis, basic laboratory techniques, and Adobe Illustrator.

We developed a series of engineering ethics modules that complemented four of the technical modules; three of the ethics modules were JEDI-focused and will be discussed here. The technical course material that interfaced with the JEDI-focused ethics modules included Systems and Synthetic Biology, Neuroengineering, and Biomedical Devices. This Teaching Tips paper introduces the relevant JEDI-focused learning objectives and lesson plan materials as well as how they complemented the technical components of the relevant modules. The paper will conclude with a discussion of student feedback, challenges, and concluding reflections.

In developing the engineering ethics curricula, we sought to achieve two aims with the JEDI-focused material: (1) for students to learn how justice, equity, diversity, and inclusion intersect with bioengineering practice through an interdisciplinary lens of history, philosophy, sociology and anthropology which provide strong scholarly frameworks and theoretical foundations and (2) for students to participate in and foster an inclusive environment within their own educational institution through effectively communicating about these topics with each other. To that end, we employed a broad definition of engineering ethics that is inclusive of both traditional considerations of risk, safety, moral philosophy, and individual professional responsibility, as well as broader, macro-ethical considerations including JEDI within the profession and among the societies and communities with whom bioengineers engage or impact, both directly and indirectly.[26] We advocate that JEDI-focused considerations within the profession and the broader society are inherently ethical considerations. Within this broad umbrella of engineering ethics, we center the social responsibility of bioengineers with regards to their own professional community, as well as other stakeholder communities on local to global scales.

This approach builds on a rich body of literature that considers engineering practice to be a socio-technological endeavor and advocates for educating engineering students with interdisciplinary knowledge from the humanities, including science and technology studies (STS) and the history and sociology of science and technology.[32,35] Our approach also incorporates the framing of engineering ethics to be inclusive of both micro-ethics, which focuses on individual agency, and macro-ethics, which emphasizes broader societal forces and systemic contexts. For example, Herkert argues for more inclusion of the social elements of engineering practice and a macro-ethics approach, placing engineering practice within its broader societal context in engineering ethics education.[25] We are also building upon important scholarship that motivates and empowers the connection between JEDI and engineering ethics education, as well as numerous educational initiatives to embed social justice curriculum within engineering education.[5,7,17,29,30,48] In the novel initiative presented here, it is our goal to contribute to this literature and explicitly connect JEDI considerations to engineering ethics pedagogy.

For each of the JEDI-focused engineering ethics modules, we designed a lesson plan including learning objectives, assigned readings, a discussion board homework assignment, small group activities and an ethics instructor moderated class discussion. Our approach to each module was to introduce students to the relationship between bioengineering practice and society, specifically as it intersects with justice, equity, diversity and inclusion, within the context of specific sub-fields or applications. Through the assigned readings, we provided frameworks from interdisciplinary scholarship inclusive of approaches to civil discourse about biotechnologies as well as scholarly studies of the intersection between biotechnologies and society. For each module, students were presented with a reading, podcast or set of readings. They then were assigned to write an individual reflection to be shared on a discussion board. The class meetings included small group activities as well as seminar-style discussions. This allowed the students to approach the material from multidisciplinary perspectives, to practice articulating their own views in writing and discussion, and to read and listen to their peers' perspectives. These pedagogical approaches of teaching engineering ethics and JEDI-focused content through multidisciplinary scholarship and combining individual and collaborative work are supported by the secondary literature.[24,27,32,42]

The modules were designed cumulatively, allowing students to apply concepts from earlier modules to later material. While the class had an enrollment of 69 students, the discussion boards and class meetings were held in four different groups, each with 16-18 students. Due to COVID-19 restrictions, all discussions were held via Zoom.

### *Module 1: Systems and Synthetic Biology*

The Systems and Synthetic Biology material included one class of technical content followed by one class of JEDI-focused ethics content. The technical content included a series of mini-lectures ranging from 5 to 20 minutes introducing the students to research areas such as systems biology of cell signaling, the neural connectome and epigentic mechanisms, and optogenics. These mini-lectures were prerecorded TED talk style lectures produced by the department's faculty explaining their labs' research programs. At the conclusion of the technical lectures, students completed an online quiz to assess their comprehension of the material.

In tandem with the technical material, we designed JEDI-focused learning objectives to prompt the students to understand how advances in systems and synthetic biology can have dramatic societal implications and thus, how bioengineers have a responsibility to identify and engage with diverse stakeholders outside of their technical practice. We designed the module to introduce the students to the concepts of democratic deliberation and ethics education and then to have the students consider a specific example of how bioengineers have demonstrated professional responsibility within this field.

Drawing from political science, the lesson plan was designed to provide the students with a foundation in the theoretical framework of democratic deliberation. Democratic deliberation can be defined as "a method of decision making in which participants discuss and debate a question of common concern, justifying their arguments with reasons and treating one another with mutual respect, with the goal of reaching an actionable decision for policy or law, open to future challenge or revision."[45] The Obama administration's Presidential Commission for the Study of Bioethical Issues employed the method of democratic deliberation in their public policy making process.[45] This approach was based on the political science scholarship of the Commission's Chair, Amy Gutmann.[23,52]

To introduce the concept of democratic deliberation, as well as the Commission's work, we assigned a podcast produced by the Presidential Commission for the Study of Bioethical Issues. In the podcast, Gutmann describes the process of democratic deliberation in policy making for bioethical issues. Gutmann describes the Commission's approach in writing a series of comprehensive research reports on emerging biotechniologies such as neuroengineering and synthetic biology technologies. Students learned how the reports sought input from diverse communities and represented thoughtful deliberations between engineers, regulators, government officials, leaders of faith, physicians, and patient advocacy groups, among others. This framework of democratic deliberation serves as a compelling example of the multifaceted ways that bioengineering practice intersects with society and offers a tangible roadmap to inclusive civil discourse about technologies' risks and benefits. Democratic deliberation provides the students with a lens to conceptualize how to approach broad civil discourse about emerging technologies, to recognize the diversity of stakeholder groups, and to foster inclusive dialogue with those stakeholders. The Commission produced a set of teaching tools and resources that are publicly available, including modules embedding ethics within courses, case studies, and discussion guides.[46]

To provide a specific example of how bioengineers have participated in inclusive civil discourse as defined by democratic deliberation, we then introduced the students to a contemporary example within bioengineering. The students read a *Science* article co-authored by leading synthetic biologists and engineers working with CRISPR-*Cas*9 in which the authors enumerate the potential risks and benefits of the technology, as well as a call for more dialogue among the scientific community, private industry, regulators and the public.[6] Again, the theme emphasized the importance of an inclusive, equitable, and democratic deliberative process addressing the risks and benefits of a new bioengineering technology within society. As recognized in both pieces, unanimous agreement on new technologies may never be reached; but having a transparent, inclusive, and equitable process in which all stakeholders' voices are heard and respected leads to a much fairer outcome and builds trust between the communities of engineers and other stakeholders.

Prior to our synchronous class meeting, the students were assigned homework to reflect on the material from the podcast and the *Science* article by contributing to an online discussion board to ensure they individually reflected on the material and considered the viewpoints of their peers. Students were asked: (a) how Gutmann describes the concepts of democratic deliberation and ethics education and (b) what they found compelling (or not) about the *Science* article and why.

For the synchronous Zoom class meeting, we first led a discussion in which the students demonstrated their comprehension of the assigned podcast and article, then we challenged the students to analyze the material by prompting them to identify and share their own values and hear the perspectives of others. For example, students were asked to share which quote from the *Science* article they found to be compelling (or not). As students shared their answers, we identified common themes among the responses, such as a focus on the importance of inclusivity, transparency, and trust among bioengineers with the public.

To simulate democratic deliberation and an inclusive civil discourse, the students were then prompted with a small group activity to identify a new technology that could pose similar benefits and risks such as CRISPR-*Cas*9. Then, they developed an approach to identify which stakeholders and communities they would consult as they considered the benefits and risks of the technology. At the conclusion of the exercise, the student groups reported back to the class identifying their key stakeholder groups, such as patient advocates, physicians, leaders of faith, and regulators, as well as what perspectives those stakeholder groups offered. This exercise allowed the students to actively contemplate the concerns of the communities of interest that may be impacted by their future work, a critical step in democratic deliberation.

### *Module 2: Neuroengingeering*

The second JEDI-focused engineering ethics module followed the technical unit covering neuroengineering. The technical unit included a series of mini-lectures introducing the students to areas of research and clinical applications within neuroengineering. The material began with an overview of the mechanisms of common neurological diseases such as Alzheimer's disease, epilepsy and Parkison's disease. The following mini-lectures introduced the students to the development of technologies to study and modulate neural function, such as bioelectronic and neuroelectronic interfaces. The technical unit concluded with a quiz to assess the students' understanding of the material.

Once the students were introduced to the technological capabilities of neuroengineering, we then wanted to ensure that they also had an introduction to the principles of biomedical ethics and moral philosophy as applicable to bioengineering practice. To establish a scholarly framework of moral philosophy and bioethics, the students read a *Neuron* article by Martha Farah, a neuroscientist and Director of the Center for Neuroscience & Society at Penn.[18] This article introduced the students to fundamental principles of bioethics that are critical for achieving JEDI aims, such as: personhood, dignity, commodification, rights, and the Beauchamp and Childress Principles of Bioethics (respect for autonomy, beneficence, nonmaleficence, and justice).[9] Farah also introduces the concepts of consequentialism and deontology.[3,51] The article expounds upon these principles and theories as they apply to human research subjects, brain computer interfaces, and other areas within neuroengineering.

We also assigned an article about proactive ethical design within neuroengineering assistive and rehabilitation technologies.[28] Through this reading, the students were asked to consider how the diversity of end-users of neuroengineering, assistive and rehabilitative technologies impacts the successful implementation of the designs through an analysis of "the convergence of user-centered and value-sensitive" design theories and applications. The article specifically details the design philosophies of user-centered design and value-sensitive design, both of which center a more inclusive set of stakeholders in the design process from ideation through development.[1,20,54,55,57]

For their homework, students were asked to write a discussion board post reflecting on both articles. First, we asked an open-ended question to prompt self-reflection, asking if any of the specific principles of biomedical ethics or moral philosophy resonated with them. Then, we asked them to relate that principle or philosophy to bioengineering practice specifically. We also asked the students to consider how the proactive ethical design philosophies might impact technological development.

For the synchronous class meeting, the focus was on collaborative work followed by a class discussion of the material. The first activity involved stakeholder mapping, similar to the first module, but with the addition of also recognizing varying levels of agency among the stakeholders. The students were asked to work in pairs or small groups and imagine an ethical dilemma or case study within neuroengineering. Students could imagine a hypothetical example or select an ethical dilemma from the assigned readings. Then, the students were challenged to identify the key stakeholder groups while also considering their level of autonomy in the decision-making process about the ethical dilemma. Students identified stakeholder groups such as patient advocates, patients, physicians, researchers, health insurance companies, hospitals, regulatory bodies, bioethicists, and institutional review boards. Finally, the students were then asked to apply the concepts and principles from the readings that they thought would help them navigate potential policy making recommendations or civil discourse. For example, students discussed the societal context of cochlear implants among pediatric patients. In such discussions, the JEDI-focused principles of bioethics such as patient autonomy and the proactive design philosophies such as value-sensitive design were illuminated.

### *Module 3: Biomedical Devices*

The third JEDI-focused engineering ethics module was embedded within the technical unit covering Biomedical Devices which spanned several classes. The first class introduced students to biomedical devices through a series of mini-lectures focusing on the design and manufacturing of biotechnologies to diagnose, prevent or treat disease. Example technologies included robot-mediated rehabilitation devices, diagnostic devices, and tissues-on-a-chip. The second class introduced the students to Adobe Illustrator through a series of online tutorials.

While the students were being introduced to the broad capabilities of biomedical devices, as well as the technical skills to use Adobe Illustrator, we wanted to provide the students with frameworks to identify and address concerns of equity and diversity with regards to biomedical device design. The content was meant to address two learning objectives: (1) for students to be able to illustrate how equitable access to medical technologies and care should impact engineering design and (2) for students to be able to explain how diversity among the users of biomedical technologies, including patients, practitioners, and others, should impact engineering design.

To provide theoretical frameworks for understanding the moral imperative of justice, equity, diversity and inclusion within the biomedical device design process, the students were assigned to read anthropologist Amy Moran-Thomas's article on the racial bias of the pulse oximeter.[39] Moran-Thomas tells the history of how many pulse oximeters were calibrated on people with light skin, leading to errors among people with darker skin tones and how many of these pulse oximeters are still used in clinical practice today, leading to biased readings of what is meant to be an objective data point. The article then contextualizes this technological example within a deeper history of systemic racism and inequities. Moran-Thomas introduces scholarship and theoretical frameworks, including Ruha Benjamin's concept of "discriminatory design," Toni Morrison's framework of repair work, and Sara Ahmed's scholarship on institutional cultures.[2,10,40]

The students were assigned to write a discussion board post responding to Moran-Thomas's article by selecting a quote or brief passage to share with the class. They were instructed to discuss what they found to be particularly compelling about it or what resonated with them.

The class meeting was designed to facilitate an ethics instructor moderated discussion as well as a design challenge in small groups. For the class discussion, we began the meeting by asking to the students to identify the technological problem with the pulse oximeter as described in the article, as well as its consequences for racial discrimination with regards to clinical outcomes, access to care, impact on caregivers and economic significance. Then, the students were asked to consider what other biomedical applications, technologies or systems might pose the same problems and how those can be addressed based on the article and the literature it cited.

After the class discussion, the students were then instructed to work in pairs and share the quotes that they discussed on the discussion board, as well as their overall response to the article. They were also instructed to synthesize their thoughts on the social significance of the pulse oximeter on clinical outcomes, access to care and caregiver burden.

Following the discussions among pairs, we wanted the students to have the opportunity to voice their thoughts as well as benefit from hearing the diversity of voices among their peers in the larger group. We had each pair report back on the specific themes they discussed. This was followed by a discussion in which the students were asked to apply the material from previous units to this case study, such as the principles of biomedical ethics, moral philosophy, and proactive design philosophies.

In the final portion of the class meeting, we gave the students a design challenge in which they were instructed to apply what they had learned throughout the JEDI-focused ethics modules, as well as their technical skills with Adobe Illustrator. In small teams of 2-4 students, each team was assigned the same design challenge to create a schematic for a wearable thermometer, but the teams were told to first imagine their end user and any of the user's unique requirements. The teams designed schematics for different imagined users, such as an infant, an athlete, or a hospitalized patient. The students then presented their concept to the class and explained the unique features that addressed the particular needs of their imagined end user. They also described how they addressed considerations of equitable access to the technology, including its cost, availability and potential scalability. The homework for the class meeting was for each student to individually create a schematic of the design using Adobe Illustrator, directly connecting the JEDI-focused ethics material to their technical skills.

To reinforce the themes from the class meeting, we concluded with a discussion on how considerations of the diversity of patients, clinical trial participants and consumers, as well as prioritizing justice, diversity, equity, and inclusion, can and should impact bioengineering design decisions.

## REFLECTION

### *Student Feedback*

At the conclusion of the semester, the students were invited to complete a survey that inquired about their experience with the engineering ethics content. IRB review exemption was authorized by the University of Pennsylvania's Institutional Review Board (IRB Protocol# 850997). Forty-one students completed the Qualtrics survey which included a series of five questions with a seven-point Likert scale and one open-ended question. The responses indicated that a majority of the respondents agreed that the ethics modules were interesting (98%), helped them reflect on their professional goals (89%), and would like to see future engineering courses include ethics modules (88%). All respondents agreed that the engineering ethics modules helped them to consider the societal context of engineering practice and that ethics is an important component of an engineering education. The open-ended responses also indicated a positive reception to the material. Comments emphasized that the engineering ethics modules highlighted important issues and allowed for productive classroom dialogue. Responses included:

> These modules helped me realize certain medical biases, societal contexts, and pressing issues that are relevant in bioethics today, and I appreciated the opportunity to voice my concerns about these issues, as well as the avenues of conversation opened up while we engaged in the live discussions!

> I think this is a vital program that brings up topics that otherwise may go unnoticed. I truly think it is something that deserves greater emphasis and should continually be taught.

> I thought that these discussions made me stop and think about why I want to do engineering and it helped educate me about issues in the world that I may not have been aware of before. When I watch the news now about scientific discovery related topics, I now think about what we discussed in our ethics discussions and apply ideas to these situations. I think that these modules taught me a lot about something I wouldn't necessary have learned about otherwise.

### *Author's Reflection*

Challenges to be addressed for the expansion of the pilot program into other core engineering courses largely include availability of faculty to develop the material as well as time constraints within densely packed syllabi. To develop engineering ethics and JEDI-focused modules, we found an interdisciplinary team involving expertise in history, sociology, philosophy, cognitive science, and bioengineering to be particularly productive and robust, while also recognizing it requires continual institutional support. Furthermore, we had the advantage of working with a course that was being newly designed. Thus, the engineering ethics modules were original components of the new iteration of the course, eliminating the burden of embedding ethics content into a preestablished and full syllabus.

Instructors may want to consider assessing the pedagogical approaches to JEDI-focused ethics modules. The survey collected student opinions on all the engineering ethics modules and was intended to gauge student engagement with the ethics material in general. The survey did not explicitly ask the students to reflect on the JEDI-focused content. The survey, for example, could be redesigned to inquire if and how the course impacted the students' sense of inclusivity, as well as their personal identity as an engineer.

## *Conclusion*

The pilot program aimed to provide a cohort of first-year Bioengineering students with an introductory foundation on JEDI-related scholarship, including principles of bioethics, moral philosophy, and interdisciplinary studies from history, sociology, and anthropology of technology. The material was designed to provide the students with concrete knowledge, historical context, and analytical skills to recognize and address JEDI issues, challenges, and opportunities as they relate to bioengineering practice. Furthermore, by centering this material within a core technical course and inviting the students to participate in meaningful dialogue about topics such as the intersection between bioengineering practice and social justice, the instructors were able to demonstrate to the students that JEDI are important values held by the faculty, department, and university. Ultimately, the JEDI-focused modules were meant to foster inclusion for the students while also providing specific domains of knowledge to engage in productive dialogue and design equitable and just biotechnologies.

Based on the student feedback, the fall 2020 pilot program to introduce engineering ethics material, including JEDI-focused modules, into the Introduction to Bioengineering course was found to be fruitful. The department moved forward with repeating the modules in the fall 2021 offering of the class as well as expanding the initiative to develop additional modules in the sophomore curriculum (Tables 1, 2, 3, 4).

**TABLE 1. JEDI-Focused Engineering Ethics Module 1: Systems and Synthetic Biology Lesson Plan**

| Lesson Plan | |
|---|---|
| Technical Content | The technical content introduced students to the fields of systems and synthetic biology through a series of mini-lectures focusing on areas of research and clinical applications, such as the development of technologies to control or manipulate biological interactions or functions. Specific examples included optogenetics, epigenetics, and CAR T-cell therapy. |
| JEDI-Focused Engineering Ethics Learning Objectives | • Students will be able to recognize the importance of democratic deliberation and ethics education with regards to bioengineering practice<br>• Students will be able to evaluate an example of how bioengineers demonstrated professional responsibility for an emerging technology by communicating the risks and benefits to the public and making a call to action for public discourse |
| Key Concepts | • Democratic deliberation<br>• Ethics education |
| Assigned Readings | • "Ethically Sound: Bioethics for Every Generation" podcast[53]<br>• "A prudent path forward for genomic engineering and germline gene modification," *Science*[6] |
| Discussion Board Prompts | • Amy Gutmann served as the Chair of the Presidential Commission for the Study of Bioethical Issues, which produced a series of reports and policy papers from 2009-2017. Listen to or read the transcript of the podcast, "Ethically Sound: Bioethics for Every Generation," and take notes on how Gutmann describes the concepts of democratic deliberation and ethics education. How does Gutmann describe the concepts of democratic deliberation and ethics education?<br>• In 2015, a group of 18 bioengineering researchers published a policy piece in *Science* in which they described their pioneering work with CRISPR-*Cas*9 in its societal context. As you read this article, pay attention to how they describe the technology, its current and potential applications, and their recommendations for public policy. Highlight a compelling quote and be prepared to discuss it with the class. What did you find compelling (or not) about the *Science* article and why? |
| Class Activity | Lead a class discussion based on the following discussion prompts:<br>• How would you define "democratic deliberation" in your own words?<br>• What role do you think STEM professionals play in effective public discourse?<br>• Identify a compelling quote from the *Science* article to share with the class.<br>• What themes do the quotes have in common?<br>• Identify the benefits, risks, and ethical considerations presented.<br>• If you were to develop a technology that posed similar benefits and risks, what approach would you take to identify and address the ethical issues?<br>• What stakeholders would you consult? |

**TABLE 2. JEDI-Focused Engineering Ethics Module 2: Neuroengineering Lesson Plan**

| Lesson Plan | |
|---|---|
| Technical Content | The technical content introduced students to the field of neuroengineering through a series of mini-lectures focusing on areas of research and clinical applications. The material began with an overview of the mechanisms of common neurological diseases such as Alzheimer's disease, epilepsy and Parkison's disease. The following lectures introduced the students to the development of technologies to study and modulate neural function, such as bioelectronic and neuroelectronic interfaces. |
| JEDI-Focused Engineering Ethics Learning Objectives | • Students will be able to describe the principles of biomedical ethics and demonstrate how moral philosophy can be applied to biomedical engineering<br>• Students will be able to identify the various stakeholders in bioengineering practice, including patients, clinical trial participants, researchers, funding agencies, regulators and others |
| Key Concepts | • Consequentialism, deontology, personhood, dignity, commodification, and rights<br>• Beauchamp and Childress Principles of Bioethics: respect for autonomy, beneficence, non-maleficence, and justice<br>• User-centered design, value-sensitive design |
| Assigned Readings | • "An Ethics Toolbox for Neurotechnology," *Neuron*[18]<br>• "Proactive Ethical Design for Neuroengineering, Assistive and Rehabilitation Technologies: the Cybathlon Lesson," *Journal of NeuroEngineering and Rehabilitation*[28] |
| Discussion Board Prompts | • Reflect on Martha J. Farah's article, "An Ethics Toolbox for Neurotechnology," in *Neuron*. Did any of the specific principles of biomedical ethics or moral philosophy resonate with you? How do you see it being relevant to bioengineering practice?<br>• Consider the article "Proactive Ethical Design for Neuroengineering, Assistive and Rehabilitation Technologies: the Cybathlon Lesson," in *Journal of NeuroEngineering and Rehabilitation*. How might a user-centered or value-sensitive design impact technological development? |
| Class Discussion Prompts | • Reflect on the assigned readings and share what you wrote in your discussion board post |
| Class Activity | Neuroengineering Stakeholder Mapping<br>• Ask the students to brainstorm ethical dilemmas and case studies within neuroengineering. They may reference the assigned readings.<br>• Then, ask the class to select one of the ethical dilemmas or case studies identified which they will further examine.<br>• Stakeholder Mapping: Ask the students to "think-pair-share" a list of stakeholders. First, ask the students to individually brainstorm their ideas. Then, ask them to share with a partner. Finally, as a class, create a visual aid that identifies the various stakeholders, indicating their level of autonomy in the decision-making process. For example, students may indicate stakeholders such as: patients, physicians, researchers, health insurance companies, hospitals, regulatory agencies, bioethicists, IRBs, and others.<br>• Analysis: Ask the students to itemize the concepts from the readings that would help them navigate their policymaking recommendations. Examples may include: medical ethics principles such as justice, equitable access to care, or user-centered design, as applicable. |

**TABLE 3. JEDI-Focused Engineering Ethics Module 3: Biomedical Devices Lesson Plan**

| Lesson Plan | |
|---|---|
| Technical Content | The technical content included two class meetings worth of material. The first class meeting introduced students to biomedical devices through a series of mini-lectures focusing on the design and manufacturing of biotechnologies to diagnose, prevent or treat disease. Example technologies included robot-mediated rehabilitation devices, diagnostic devices, and tissues-on-a-chip. The second class meeting introduced the students to Adobe Illustrator through a series of online tutorials. |
| JEDI-Focused Engineering Ethics Learning Objectives | • Students will be able to illustrate how equitable access to medical technologies and care should impact engineering design<br>• Students be able to explain how diversity among the users of biomedical technologies, including patients, practitioners and others, should impact engineering design |

**TABLE 3. continued**

| Lesson Plan | |
|---|---|
| Key Concepts | • Discriminatory design<br>• Racial bias |
| Assigned Readings | • "How a Popular Medical Device Encodes Racial Bias," *Boston Review*[39] |
| Discussion Board Prompts | • Select a quote or brief passage from the article that you found compelling. Discuss what resonated with you about that passage. |
| Class Discussion Prompts | • Identify the technological problem with the pulse oximeter as described in the article, as well as its consequences for racial discrimination with regards to clinical outcomes, access to care, impact on caregivers, and economic significance.<br>• What other applications, technologies or systems might pose the same problems and how can those be addressed based on the article and the literature it cited?<br>• Work in pairs and share the quotes you discussed on the discussion board as well as your overall response to the article. Synthesize your thoughts on the social significance of this particular device on clinical outcomes, access, and caregiver burden.<br>• As a pair, report back on the specific themes you discussed.<br>• How might you apply the principles of biomedical ethics and theoretical frameworks from the prior modules to this discussion? |
| Class Activity | • Assign students to small teams.<br>• Give each team the same design challenge (i.e., wearable thermometer), but with a different end user (i.e., infant, athlete, hospitalized patient).<br>• Ask each group to present their design to the class, explaining the unique features in response to the particular needs of their end user.<br>• Students should address the following questions in their presentation: How did considerations of equitable access to the technology impact your design? How might cost, availability, and scalability impact your design choices? How did the particular needs of the assigned end user impact your design decisions?<br>• Homework: Students should individually create schematic of the design using Adobe Illustrator. |

**TABLE 4. Engineering Ethics within Introduction to Bioengineering Evaluation**

| Statement | Percentage of Students Who Agreed with Each Statement (%) |
|---|---|
| The ethics modules were interesting | 98 |
| The ethics modules helped me consider the societal context of engineering practice | 100 |
| The ethics modules helped me reflect on my professional goals | 89 |
| I would like future engineering courses to include ethics modules | 88 |
| I think ethics is an important component of an engineering education | 100 |

Students responded on a 7-point Likert scale. Percentage of students who strongly agreed, agreed, or somewhat agreed with each statement is indicated.

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## REFERENCES


[1]Abras, C., D. Maloney-Krichmar, and J. Preece. User-Centered Design. In: Encyclopedia of Human-Computer Interaction, edited by W. Bainbridge. Thousand Oaks: Sage, 2004.

[2]Ahmed, S. On being included: Racism and diversity in institutional life. Durham: Duke University Press, 2012.

[3]Alexander, L and Moore, M. Deontological Ethics. The Stanford Encyclopedia of Philosophy. Winter 2021 Edition. Edward N. Zalta (ed.). https://plato.stanford.edu/archives/fall2021/entries/consequentialism/. Accessed 02 Aug 2022.

[4]Atadero, R. A., C. H. Paguyo, K. E. Rambo-Hernandez, and H. L. Henderson. Building inclusive engineering identities: implications for changing engineering culture. *Eur J Eng Educ* 43(3):378–398. https://doi.org/10.1080/03043797.2017.1396287.

[5]Baillie, C., A. Paweley, and D. Riley (eds.). Engineering and Social Justice: In the University and Beyond. West Lafyette, IN: Purdue University Press, 2011.

[6]Baltimore, D., P. Berg, M. Botchan, D. Carroll, R. A. Charo, G. Church, J. E. Corn, G. Q. Daley, J. A. Doudna, M. Fenner, H. T. Greely, M. Jinek, G. S. Martin, E. Penhoet, J. Puck, S. H. Sternberg, J. S. Weissman, and K. R. Yamamoto. Biotechnology A prudent path forward for genomic engineering and germline gene modification. *Science* 348(6230):36–38. https://doi.org/10.1126/science.aab1028.

[7]Barry, B. E., and J. R. Herkert. Chapter 33: Engineering Ethics. In: Cambridge Handbook of Engineering Education Research, edited by A. Johri, and B. M. Olds. Cambridge: Cambridge University Press, 2014.

[8]Baumer, B. S., R. L. Garcia, A. Y. Kim, K. M. Kinnaird, and M. Q. Ott. Integrating data science ethics into an undergraduate major: a case study. *Journal of Statistics and Data Science Education* 30(1):15–28. https://doi.org/10.1080/26939169.2022.2038041.

[9]Beauchamp, T. L., and J. F. Childress. Principles of Biomedical Ethics, 7th ed. New York: Oxford University Press, 2019.

[10]Benjamin, R. Race after technology: Abolitionist tools for the new Jim code. Oxford: Polity, 2019.

[11]Busch-Vishniac, I., and J. Jarosz. Can diversity in the undergraduate engineering population be enhanced through curricular change? *J Women Minorities Sci Eng* 10(3):255–281.

[12]Canary, HE, Herkert, JR, Ellison, K, Wetmore, JM. Microethics and macroethics in graduate education for scientists and engineers: Developing and assessing instructional models. Proceedings of American Society for Engineering Education (ASEE) Annual Conference and Exposition, San Antonio, TX. June 10–13, 2012. Paper ID #2012-3569. 16 pp.

[13]Cruz, J. A., and W. J. Frey. An effective strategy for integrating ethics across the curriculum in engineering: An ABET 2000 challenge. *Sci Eng Ethics* 9:543–568.

[14]Cruz-Cruz, J. A., A. M. Curbelo, and W. J. Frey. Doing Ethics Across the Curriculum: The EAC toolkit. *Teaching Ethics* 10:47–69.

[15]Davis, M., and K. Riley. Ethics across the graduate engineering curriculum: An experiment in teaching and assessment. *Teaching Ethics* 9(1):25–42.

[16]Douglas EP, Holbrook JB. Engineering Ethics Education for Social Justice. In 2020 IEEE Frontiers in Education Conference (FIE) 2020 Oct 21:1-5.

[17]Douglas EP, Holbrook JB. Engineering Ethics Education for Social Justice. In 2020 IEEE Frontiers in Education Conference (FIE) 2020 21:1-5.

[18]Farah, M. J. An ethics toolbox for neurotechnology. *Neuron* 86(1):34–37. https://doi.org/10.1016/j.neuron.2015.03.038.

[19]Farrell, S., Al. Godwin, and D. Riley. A sociocultural learning framework for inclusive pedagogy in engineering. *Chem Eng Educ* 55(4):192–204. https://doi.org/10.18260/2-1-370.660-128660.

[20]Friedman, B., and P. H. Kahn. Human values, ethics, and design. In: The Human-Computer Interaction Handbook. London: CRC Press, pp. 1267–1292, 2007.

[21]Goodman, I, Cunningham, C, Lachapelle, C, Thompson, M, Bittinger, K, Brennan, R, et al. Final report of the Women's Experiences in College Engineering Project. Cambridge, UK: Goodman Research Group, 2002.

[22]Grosz, B., D. G. Grant, K. Vredenburgh, J. Behrends, L. Hu, A. Simmons, and J. Waldo. Embedded EthiCS: integrating ethics across CS education. *Commun ACM* 62:54–61. https://doi.org/10.1145/3330794.

[23]Gutmann, A., and D. Thompson. Why Deliberative Democracy? Princeton. NJ: Princeton University Press, 2004.

[24]Herkert, J. R. Engineering ethics education in the USA: Content, pedagogy and curriculum. *Eur J Eng Educ* 25(4):303–313. https://doi.org/10.1080/03043790050200340.

[25]Herkert, J. Microethics, Macroethics, and Professional Engineering Societies. National Academy of Engineering Emerging Technologies and Ethical Issues in Engineering: Papers from a Workshop. Washington, DC: The National Academies Press, 2004. https://doi.org/10.17226/11083.

[26]Hess, J. L., A. Whitehead, B. K. Jesiek, A. Katz, and D. Riley. WIP: Intersections Between Diversity, Equity, and Inclusion (DEI) and Ethics in Engineering. *IEEE Frontiers in Education Conference (FIE)* 2021:1–5. https://doi.org/10.1109/FIE49875.2021.9637059.

[27]Huff, C., and W. Frey. Moral pedagogy and practical ethics. *Sci Eng Ethics* 11(3):389–408. https://doi.org/10.1007/s11948-005-0008-1.

[28]Ienca, M., R. W. Kressig, F. Jotterand, *et al*. Proactive ethical design for neuroengineering, assistive and rehabilitation technologies: the cybathlon lesson. *J NeuroEngineering Rehabil* 14:115. https://doi.org/10.1186/s12984-017-0325-z.

[29]Johnson, D., and J. Wetmore. Technology and Society: Building our Sociotechnical Future. New York: MIT Press, 2008.

[30]Johnson, K, Leydens, L, Moskal, B, Kianbakht, S. Gear switching: From "technical vs. social" to "sociotechnical" in an introductory control systems course. In 2016 American control conference (ACC). 2016. 6640–6645.

[31]Joyce, K. A., K. Darfler, D. George, J. Ludwig, and K. Unsworth. Engaging STEM ethics education. *Engag Sci Technol Soc* 4:1–7. https://doi.org/10.17351/ests2018.221.

[32]Kline, R. R. Using history and sociology to teach engineering ethics. *IEEE Technol Soc Mag* 4:13–20. https://doi.org/10.1109/44.974503.

[33]Litchfield, K., and A. Javernick-Will. "I am an Engineer AND": A mixed methods study of socially engaged engi-

neers. *J Eng Educ* 104(4):393–416. https://doi.org/10.1002/jee.20102.
[34]Margolis, J., and A. Fisher. Unlocking the clubhouse: women in computing. Cambridge, MA: MIT Press, 2002.
[35]Martin, D. A., E. Conlon, and B. Bowe. A Multi-level review of engineering ethics education: Towards a socio-technical orientation of engineering education for ethics. *Sci Eng Ethics* 27(5):1–38.
[36]McEneaney, E., and C. Radeloff. Geoscience in social context: an assessment of course impact on attitudes of female undergraduates. *J Women Minorities Sci Eng* 6:131–153.
[37]Mikic, B., and D. Grasso. Socially-relevant design: the TOYtech project at Smith College. *J Eng Educ* 91(3):319–326.
[38]Mitcham, C., and E. Englehardt. Ethics across the curriculum: Prospects for broader (and deeper) teaching and learning in research and engineering ethics. *Sci Eng Ethics* 25(6):1735–1762. https://doi.org/10.1007/s11948-016-9797-7.
[39]Moran-Thomas, A. How a Popular Medical Device Encodes Racial Bias. Boston Review. 2020 Aug 2. https://bostonreview.net/articles/amy-moran-thomas-pulse-oximeter/.
[40]Morrison, T. Beloved. New York: Vintage, 1987.
[41]Nakamura, A. Fostering diversity and inclusion and understanding implicit bias in undergraduate chemical engineering. *J Chem Educ* 99(1):331–337. https://doi.org/10.1021/acs.jchemed.1c00422.
[42]National Academy of Engineering. 2016. Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs. Washington, DC: The National Academies Press. https://doi.org/10.17226/21889.
[43]Oehlberg, L., R. Shelby, and A. Agogino. Sustainable product design: Designing for diversity in engineering education. *Int J Eng Educ* 26(2):489.
[44]Pearson, Y. E., and D. R. Simmons. Diversity and inclusion in civil and environmental engineering. *J Professional Issues Eng Educ Pract* 144(4):02018001. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000389.
[45]Presidential Commission for the Study of Bioethical Issues. Bioethics for Every Generation: Deliberation and Education in Health, Science, and Technology. Washington, D.C.: PCSBI, 2016.
[46]Presidential Commission for the Study of Bioethical Issues. Teaching Tools. https://bioethicsarchive.georgetown.edu/pcsbi/node/5204.html . Accessed 02 Aug 2022.
[47]Puritty, C., L. R. Strickland, E. Alia, B. Blonder, E. Klein, M. T. Kohl, E. McGee, M. Quintana, R. E. Ridley, B. Tellman, and L. R. Gerber. Without inclusion, diversity initiatives may not be enough. *Science* 357(6356):1101–1102. https://doi.org/10.1126/science.aai9054.
[48]Riley, D. Engineering thermodynamics and 21st century energy problems: a textbook companion for student engagement. *Synth Lect Eng* 16(3):1–97.
[49]Riley DM, Lambrinidou Y. Canons against cannons? Social justice and the engineering ethics imaginary. In 2015 ASEE Annual Conference & Exposition 2015 Jun 14: 26.322.1-26.322.19.
[50]Rowden, K., and B. Streibig. Incorporating environmental ethics into the undergraduate engineering curriculum. *Sci Eng Ethics* 10:417.
[51]Sinnott-Armstrong, W. Consequentialism. The Stanford Encyclopedia of Philosophy. Fall 2021 Edition. Edward N. Zalta (ed.). https://plato.stanford.edu/archives/fall2021/entries/consequentialism/. Accessed 02 Aug 2022.
[52]Thompson, D. F. Deliberative Democratic Theory and Empirical Political Science. *Annu Rev Polit Sci* 11:497–520.
[53]Viers, HW. (2016, November 7). Bioethics for every generation. (Episode 9). In Ethically Sound: The Bioethics Commission. https://bioethicsarchive.georgetown.edu/pcsbi/node/5882.html.
[54]De Vito, D. A., B. A. Myers, K. R. Mc Curry, J. Dunbar-Jacob, R. P. Hawkins, A. Begey, and M. A. Dew. User-centered design and interactive health technologies for patients. *Comput Inform Nurs* 27(3):175–183. https://doi.org/10.1097/NCN.0b013e31819f7c7c.
[55]Vivas-Valencia, C, Kong, N, Kim, E, Purzer, S, and Payne, L. An Assessment Instrument for User-centered Innovation Potential Among Biomedical Engineers. ASEE Annual Conference & Exposition. *Montréal, Quebec*. https://doi.org/10.18260/1-2-34108.
[56]Van Cleave, N. Components of an American Indian computer science transfer degree program. *J Eng Educ* 90(1):55–61.
[57]van Wynsberghe, A. Designing robots for care: care centered value-sensitive design. *Sci Eng Ethics* 19(2):407–433. https://doi.org/10.1007/s11948-011-9343-6.