2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #40015

Redesign of an Engineering Failure Course to Incorporate Learning Objectives in Diversity, Ethics and Inclusivity

Dr. Gary P. Halada, Stony Brook University

Dr. Halada, Associate Professor in Materials Science and Chemical Engineering at Stony Brook University, directs an interdisciplinary undergraduate degree program in Engineering Science. He designs educational materials focused on nanotechnology, advanced manufacturing and engineering adaptation for climate change. He also works with faculty from other disciplines to explore the integration of STEM and liberal arts education.

Redesign of an Engineering Failure Course to Incorporate Learning Objectives in Diversity, Ethics and Inclusivity

Abstract:

In this presentation, we will discuss recent evolution of the course to fulfill not only the University undergraduate requirements for examining significant relationships between Science or Technology and the Arts, Humanities, or Social Sciences (STAS), but also the newly implemented requirement for courses which examine the importance of Respecting Diversity and Fostering Inclusiveness (DIV). Using the ADDIE (Analyze, Design, Develop, Implement, Evaluate) model for curriculum development, we have redesigned the course with input from a Quality Assurance advisory group, selected to better ensure that content on diversity and inclusivity is well-integrated into the course in a meaningful and effective manner. This content includes interviews with industry professionals who themselves can effectively represent diverse perspectives; readings selected from texts on engineering failures resulting from a lack of inclusivity ("missing voices") in design, and case studies on the impact of locating high risk technologies and facilities in socio-economically disadvantaged areas (often correlated with large minority populations). Students are asked to reflect on factors which impact their own values as well as those of engineers who design, site and implement technologies. DIV learning outcomes to be achieved via the course revision include (1) analyzing the impact of power and privilege on society in the context of diversity and inclusion, (2) examining how human and cultural similarities and differences influence structural and institutional inequities, and (3) critically reflecting upon how one's own personal and cultural presuppositions affect one's values and relationships. In addition to discussing the methodology of curriculum and educational material development to meet these objectives, we will present student feedback, via responses to assignments, resulting from the first implementation of the redesigned course, and the implications of this information for further enhancing course effectiveness. The methodology used in ensuring integration of diversity, ethics and inclusion learning outcomes may also provide a model for building these concepts into other engineering courses.

Background:

Ensuring an environment of diversity and inclusivity has been identified as critical to the future of the engineering profession by professional societies such as ASME (1, 2), as well as to the composition of engineering departments who prepare engineers for a globally competitive workforce (3, 4). Likewise, a number of papers have reported on the integration of aspects of diversity, equity, ethics and inclusivity into engineering coursework. This has included building these topics into first year courses by considering topics such as environmental justice and ethics considering stakeholder needs (5), and the role of ethics, bias and diversity in bioengineering (6), as well as designing problem-based learning workshops which focus on a team-forming approach which emphasizes equity, diversity and inclusion and which can be integrated into various existing courses (7). This latter study considered the difficulty of adding coursework to already oversubscribed engineering degree curriculum requirements, which often makes it prohibitive to create required standalone courses which meet the objective of teaching the importance of issues of diversity and inclusivity in engineering. In addition, the authors point out the challenge of designing a pedagogy which correlates to engineering students learning styles and which meets the challenge of ensuring that students see diversity and inclusivity as not an "added-on" soft skill requirement with limited relevance to their career goals, but as an essential consideration in real-world problems engineers must solve. In light of these considerations, we have approached this challenge by restructuring an existing course which already had been successfully structured to address engineering ethics concepts central to the nature and causes of engineering failure, by expanding the course via the logical integration of case studies and other activities focused on the impact of diversity and inclusivity (or rather the lack thereof) on failures in development, deployment and use of technology.

Effective design or redesign of a course is not a simple matter – in fact, redesign of an existing course in which the original learning objectives are still required while new objectives are to be added is a difficult process. In this case, the process is further complicated as the course instructor and developer has limited experience in design of coursework to support objectives of diversity, inclusivity and justice, and so would benefit from external expertise from not only subject experts but also in this case from those with an expanded perspective (enriched from personal experience as well as study). The methodology chosen to be employed for this task is a version of the "ADDIE" (analysis, design, development, implementation, evaluation) model.(8) While ADDIE is often used to develop new courses where teaching technology and methods must be explored before implementation, and hence is often used in design of online courses (9), in our case the course and its teaching methodology, already found to be effective, will be kept, and content correlated with new learning objectives will be the focus of the effort. This "modified" ADDIE model (illustrated in Figure 1) will focus on (i) analysis of content and objectives (including alignment with institutional requirements); (ii) design based on integration with current course content and learning outcomes; (iii) development which will leverage resources on the role of diversity and inclusion in engineering and feedback from a carefully chosen advisory group; (iv) implementation in the existing course structure; and (v) evaluation which will include data collected for accreditation.

Methodology:

ESG 201: "Learning from Engineering Disaster", a 3 credit asynchronous online undergraduate course taught to both engineering and non-engineering majors by the presenter at Stony Brook University for the past 12 years, has proved to be a successful method for teaching ethics as well as the broader societal implications of engineering processes and technological design (10). A combination of lectures, case studies, laboratory demonstrations, interviews, video site visits and team-based collaborative analysis of engineering failures and their implications (societal, environmental, economic, legal, psychological) has proved successful in teaching the role of engineers and engineering in society, as well as the importance of engineering ethics and value sensitive design (11).

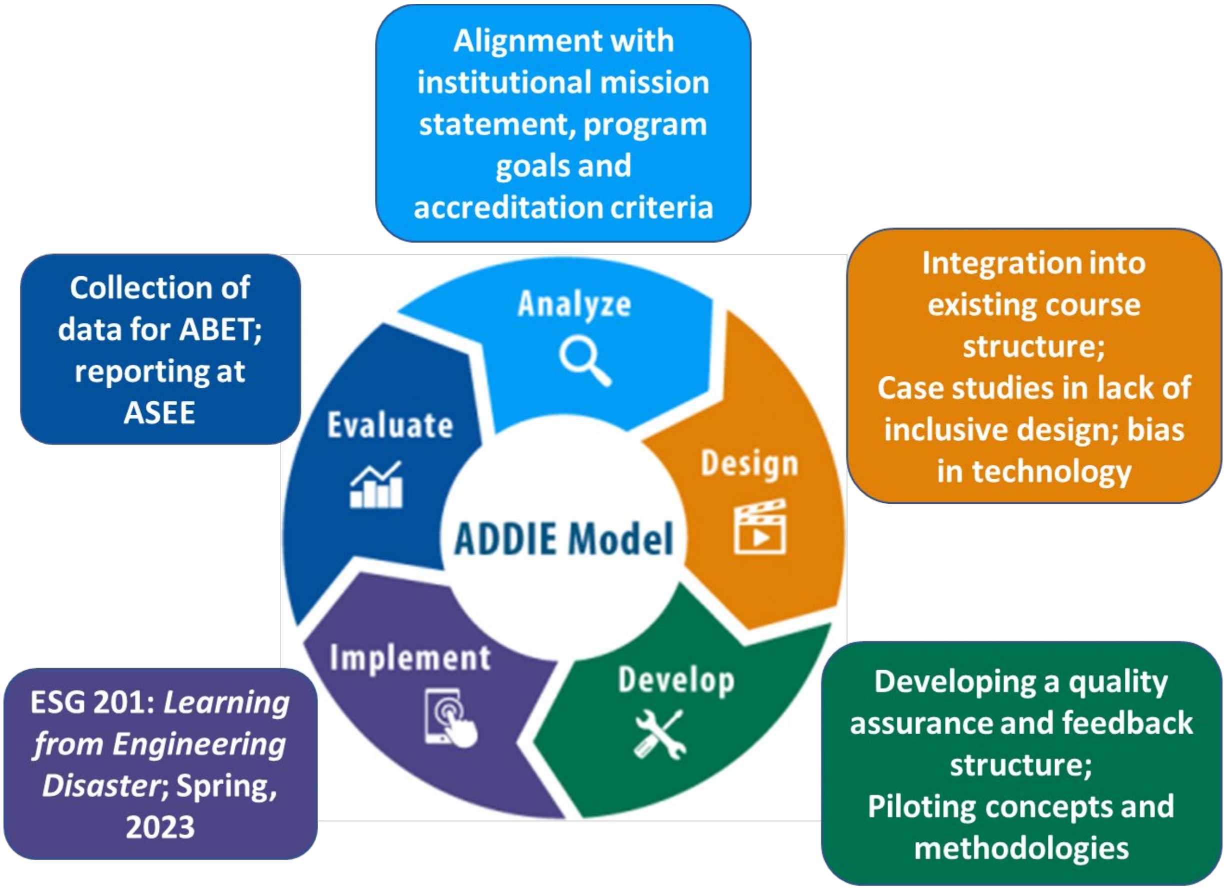

Figure 1: Adapted ADDIE model used in redesign of course on Learning from Engineering Disaster (diagram adapted from U.S. Centers for Disease Control and Prevention website, https://www.cdc.gov/training/development/addie-model.html).

It has been a required course for the B.E. program in Engineering Science, fulfilling the Stony Brook Curriculum STAS (*Understand Relationships between Science or Technology and the Arts, Humanities, or Social Sciences*) requirement (for students from many majors) and helping the Engineering Science program meet ABET accreditation requirements related to engineering ethics and broader impact of engineering design and decision making.

Starting during the summer of 2021, the course has been redesigned to enable it to fulfill the new SBC DIV requirement (*Respect Diversity and Foster Inclusiveness).* The original course has, as its stated primary objective, helping students understand the nature of engineering disaster and failure, and it doing so gain an understanding of the societal, economic and environmental impact of the engineered world. The course also serves to help students understand the nature of "risk" and how we perceive risk from engineered systems, structures and materials, the role of climate change as an engineering "threat multiplier", and how engineers learn from engineering failure (and why they must learn from these incidents to create better designs).

To reflect the inclusion of content and learning objectives related to diversity and inclusion, a revised course description was approved and reads as follows: "*The role of the engineer is to respond to a need by building or creating something along a certain set of guidelines (or* *specifications) which performs a given function. Just as importantly, that device, plan or creation should perform its function without fail. Everything, however, does eventually fail and, in some cases, fails with catastrophic results. Through discussion and analysis of engineering disasters from nuclear meltdowns to stock market crashes to climate-driven catastrophes, this course will focus on how modern engineers learn from their mistakes in order to create designs that decrease the chance and severity of failure. The impact of engineers' values and ethics, as well as the crucial role of diversity and inclusiveness on successful engineering design, will be discussed in detail.*"

<u>Course redesign, phase I:</u> To meet the DIV requirement, a new learning module was initially proposed, accompanied by appropriate readings, assigned video content, and recorded lectures incorporating a variety of case studies. In addition, specific learning outcomes on diversity and inclusiveness and an assignment focused on evaluating these learning outcomes were added, as per the description below. The evaluation of the final group project (developed as a PowerPoint presentation using VoiceThread as well as a written report) will also proposed to be modified to include assessment of factors related to diversity and inclusion.

The original course comprised six asynchronous learning modules (outcomes of which are evaluated via written assignments for each as well as a group term project) which are:

1. Course introduction – An introduction to the course, the learning outcomes, teaching methodology and expectations, and the schedule for the course.

2. Ethics and values in engineering design – General theory and background on engineering ethics (including role of professional societies) and Value-Sensitive Engineering (an approach to engineering problem solving and design which asks key questions including what types of problems engineers choose to solve (in alignment with personal values), how engineers define success, and how to investigate and avoid unintended negative implications of solutions or designs.

3. The nature of engineering risk – The role of probabilistic risk assessment, examined via theory as well as case studies in engineering disaster (includes video site visits and interviews, including a number of historic and local examples)

4. Causes of engineering disasters – Examination of causes of engineering disasters, including extreme conditions, design flaws, materials failures, and human factors. Includes video site visits as well as video laboratory demos showing how engineers use forensic techniques to analyze the technical causes of failure.

5. Complexity, a changing world, and failure – A learning module focused on climate change as a threat multiplier for engineering disaster and future engineering risk, including materials and demos on engineering adaptation to reduce risk.

To these, our original proposal was to add a sixth module at the end of the course: The role of diversity and inclusivity in avoiding engineering failure. This two to three-week module would involve a discussion of the impact a lack of gender and URM diversity has on the engineering design process, and how it can lead to failure in software and hardware for consumer and industrial technologies. We would also consider how the potential risk of disaster from a technology is increased by locating the technology in vulnerable areas which are usually economically disadvantaged (often correlated with populations with large minority demographics).

The final week of the course is allocated to allowing time for students to view each other's group final reports (which are narrated Power Point presentations in VoiceThread) in which student teams have selected recent or current engineering failures and explore their causes and broader impacts, as well as any factors related to ethics and diversity/inclusiveness and bias. Students are required to both view and comment on each other's presentations, as well to ask and answer questions from other students.

Linkage to course learning outcomes:

The current course learning outcomes are:

- Understanding the causes of engineering failure
- Understanding the nature of risk and how we perceive risk from engineered systems, structures and materials
- Understanding the societal impact of engineering failure, and engineering design
- How engineering failures have resulted in better designs
- Understanding the role of engineering ethics in engineering failures and disasters

To this we will address several of the Stony Brook Curriculum learning outcomes for "Respect Diversity and Foster Inclusiveness" (DIV) These learning outcomes, detailed at https://www.stonybrook.edu/sb/bulletin/current/policiesandregulations/degree_requirements/DIV.php, are:

1. Describe and analyze the impact of power and privilege on self and society in the context of diversity and inclusion.

2. Identify systematic barriers to equality and inclusiveness and discuss how those barriers and biases affect the perceptions of others.

3. Examine how human and cultural similarities and differences shape personal identities and influence structural and institutional inequities.

4. Critically reflect upon how one's own personal and cultural presuppositions affect one's values and relationships.

The new learning module was designed to specifically fulfill and evaluate DIV learning outcomes 1 and 3 (though aspects of learning outcomes 2 and 4 will be integrated into the course materials as well.).

The general teaching approach for this module, as with the rest of the course, is problem-based and project-based, within an online format. As an asynchronous online learning module (as are the other course learning modules), students will be presented with several supportive **readings and videos** discussing case studies in engineered devices, systems, and software considered to be failures due to embedded social bias. **Online lectures** will specifically address how a lack of inclusiveness in design teams, cognitive bias on the part of designers and implementers of technology, and lack of consideration of the needs of a diverse body of stakeholders can lead to failure. Lectures will also focus on how professional engineering societies and government bodies are playing key roles in ensuring that the voices of diverse stakeholders are heard in the engineering design process. **Video interviews with industry professionals** will be included, conducted by the instructor, to examine how the technology sector is developing mechanisms and procedures to avoid these types of failures – specifically by building diversity and inclusion into the engineering design process. **Student engagement and feedback** will be enhanced through the use of online discussion forums (which can be asynchronous) in which students are required to comment on particular case studies and engage with their peers as they analyze the causes of failure.

Specific reading assignments for the DIV learning module include excerpts from "The Alignment Problem" by Brian Christian (12), "Technically Wrong" by Sara Wachter-Boettcher (13), and “Race after Technology” by Ruha Benjamin (14). These are critically acclaimed works in the field, and each contain powerful examples and case studies of how social bias and lack of inclusivity in the design process led to failure and integrated bias in engineering design. Material for lectures will be drawn these texts as well as from recent published studies on the correlation of economic (low income) and racial demographic factors on the siting of toxic waste facilities in the United States. Further, videos associated with this learning module will include news reports on recent engineering disasters (including environmental disasters) which had a powerful impact on low income and URM communities due to increased risk factors associated with siting, poor maintenance, unsafe design and other factors linked to high risk facilities located in disadvantaged areas.

This module was designed to be accompanied by a written assignment requiring the students to explore one of these two impacts ((a) bias and lack of inclusivity in design, and (b) colocation of high risk technology in low income/minority areas) via analysis of news reports and studies focused on a particular engineering failure or enhanced risk of a technology or facility based on location near a disadvantaged or vulnerable population. Students will be asked to consider what this implies about the values of the designers or implementers of the technology, and how such problems can be avoided through Value Sensitive Design and ethical engineering principles. This includes asking students for their observations not only on where there may be shortcomings, but also how an engineering design can be improved via inclusion of “missing voices” in the design process, an invitational approach to decision making, and respect and encouragement of diversity.

Phase II: Evaluation and revision:

The course revision proposal was reviewed by faculty and staff, specialists in diversity and inclusion in education, as well as representative of a diversity of viewpoints. Selected reviewers included the Assistant Dean for Diversity and Inclusion, and several College of Engineering diversity committee representatives. The group provided feedback from three female, three male faculty members, of whom four are from underrepresented minority (URM) groups in STEM disciplines. Their comments, some of which are summarized below, provided critical feedback which has been incorporated in the final course revision.

Sample comments:

(F): "I believe it is important for students to consider gender, URM diversity, cultural and economic background differences, and overall inclusiveness during engineering design and technology development … I teach BME senior design, and we teach students that stakeholder analysis is a very important part of bioinnovation. As you mentioned in the course description, the "missing voices" could lead to design failure. Your course can be useful for all engineering students."

(F-URM): "I especially appreciate the topics outlined in the new learning objectives. The following are a few thoughts that came to mind. For your first new objective, consider including a discussion on how social location can impact access to power and privilege. To the extent possible (if you haven't already done so), center the voices of diverse scholars' when selecting course readings"

(M-URM): "I would suggest also finding ways to include these discussions throughout the other sections (learning modules) because they are found everywhere. For example, in unit 2 you discuss ethics and values. A person's background has a big impact on ethics and values and you need diverse perspectives to account for this…"

(M-URM): "I wonder if you'll get much push back from students. Every once in a while, you get a student that scoffs at diversity thinking it's a made-up problem. By having a condensed module at the end, a critique could be that this was just added to fill some a university requirement. Maybe move this unit to number 3 (after ethics and values)."

(M-URM): "The revised course description does not make the case for diversity implication, where it is only a phrase in a sentence! It can easily be missed by a reader! Regarding the 6 modules, I would try to infuse diversity-relevant contents into each of the 5 old ones, in addition to the new one which is diversity-focused."

As a result of input from the advisory group, the course has been revised to integrate issues of diversity and inclusivity throughout the learning modules. This has also resulted in integrated assignments for each module, which consider not only the learning outcomes previously taught, but also specific questions which explore each of these factors through the lens of diversity and inclusion. To further emphasize the engineering risk which is inherent in a lack of diversity, missing voices in design, and inherent bias (including socio-economic bias), one case study module was removed (which focused on emerging energy needs as a risk factor) to provide sufficient time for discussions and new active learning elements.

The advisory group will be involved in the evaluation of the first redesigned course offering, and has agreed to provide feedback on student outcomes.

Implementation and results (a work in progress):

The final revised course is currently being offered. As this is a work in progress, assessment data is limted though will be presented at the ASEE conference which follows course completion. However, students in a course co-taught by the author, on Modes of Knowledge for the Honors College, afforded the opportunity to test an assignment in which students are asked to reflect on an example of bias expressed in the design of technology, in particular focusing on a technology they use or with which they have had personal experience. In preparation for the assignment, students read selections from “Race after Technology” by Ruha Benjamin and “Technically Wrong” by Sarah Wachter-Boettcher, as well as several related articles and viewed several related videos with examples of racial or gender bias expressed in design. The resulting essays focused on the following examples chosen by the students:

- Gender bias in automobile design (airbags, restraints, issues regarding safety of pregnant drivers, etc.) and resulting increased risk to female drivers
- Lack of Middle Eastern American representation in demographic polls (resulting in inaccurate computational modeling for decision making)
- The “halo effect” and resulting social media bias (The halo effect is a social bias that occurs when, after one forms an impression on a single trait or characteristic of another person, they then erroneously generalize other traits to that person. (15)
- Bias against left-handed users in design of manually operated technology (Students also discussed cultural bias variations from country to country).
- Bias in design of artificial intelligence/machine learning algorithms
- Biases favoring men over women in hiring and credit applications
- Racial bias in health care assessment and treatment algorithms
- Racial bias in software used in sentencing and law enforcement
- Socioeconomic bias in architectural design for urban areas
- Racial bias in camera and photography development.
- Racial bias at bias against recent immigrants in development of speech recognition software
- Racial bias in facial recognition software and AI systems

100% of the student essays (20/20) discussed the crucial need for inclusivity in the engineering design process as a way to decrease bias and increase safety and success in design of technological solutions. Many (10 out of 20) also raise the issue of the impact of systemic racism on technology design. In addition, student reflections showed an enhanced appreciation of the role of bias in technology failure. For example:

Student A: “*The racial bias behind camera development has obstructed the portrayal of true humanity. The device has historically been known to disregard darker colors- especially those present in skin tone. We must acknowledge this issue by addressing the racial marginalization of darker individuals through photography. Photography companies can include people of color in the camera development process in order to better set a standard for cameras to pick up light across a diverse set of ranges. These efforts not only can contribute to the quality of the camera, but also further humanize and value the presence of all individuals, further moving towards an inclusive world.”*

Student B: “*Excluding people with accents in the design of the speech recognition software can* *lead to more serious consequences, such as feelings of inferiority and loss of identity. Since the speech-to-text software pushes for "standard" English, greater senses of language insecurity in people of color and other immigrants may arise. .... On a more general scale, tech industries should also strive to have a workforce with people from various ethnic backgrounds and different outlooks of life. By doing this, there will be a greater variety of voices involved in the design of new technological software, allowing for biases and flaws to be picked out more easily before the design is sent out to the general public*."

Student C: "*For AI (artificial intelligence) to become more knowledgeable without learning negative stereotypes, epistemology must be factored into the process as well. As we become more knowledgeable and aware of the biases that could arise from even the most trivial information, the more easily identifiable the biases within the system will become. As the training data sets and design teams become more diverse and inclusive, more access and opportunities are available for everyone, even marginalized communities, making AI a very effective tool in our society. However, when we lack the proper knowledge and data on minority groups, AI can never be as successful as it has the potential to be. It is only when all groups are equally represented in the data used to train artificial intelligence systems and the teams that develop these programs that people will be able to properly trust AI to take on significant roles in our society*."

Redesigned Learning Modules for Current Course Offering:

As of the writing of this paper, the first iteration of changes in the course learning modules has been made, and assessment data (in the form of student responses to assignments) is being collected. This data will be fully available for presentation at the ASEE annual conference; however, we can present some of that feedback here.

The redesigned learning modules, integrating diversity and inclusivity topics throughout the course (as advised), are as follows:

Redesigned learning modules				
	General focus	**Diversity-related focus**	**Diversity-related content**	**Assessment of diversity-related learning**
1	Intro to course; definition of an engineering disaster	Factors leading to failure	Inclusion of examples resulting from a lack of inclusion and failures which impacted disadvantaged populations	Student online discussion forum (students can site any disaster or failure and discuss)
2	Nature of engineering design, problem solving, and the role of ethics and values;	Integration of values of inclusivity and diversity in the engineering design process	Lecture with examples of socially responsible engineering; examples discussing problems due to lack of consideration of gender and diverse body types (ergonomics); "missing	Listing of ways inclusivity and diversity may be integrated at each stage of the engineering design process

	Integration of values of safety, reliability or reduction of risk of failure at each stage of the engineering design process		voices" in the design process leading to bias in speech-to-text software	
3	Risk and reliability; probabilistic risk assessment; role of vulnerability, cost and mitigation in engineering risk	Introduction to bias in design of technologies and location of high-risk facilities.	Lecture content on: bias in training data leading to failure (disparities) in AI/machine learning systems; vulnerability of disadvantaged communities to climate change; and impact on marginalized communities of hazardous waste sites.	Assignment on trustworthiness of machine learning systems for risk assessment; and impact on "vulnerability" of infrastructure due to location in socioeconomic disadvantaged or marginalized communities (and how this impacts the "cost" of failure to those communities).
4	Causes of failure and failure analysis; analysis of historical disasters; introduction to laboratory testing methods	Not specific to diversity and inclusion.	Mentioned in context of impact of historical disasters (for example, train wrecks impacting communities)	Not specifically addressed in this module.
5	Complexity and failure; role of threat multipliers in a changing world; Climate change as a threat multiplier	Interplay between climate change and lack of resources in disadvantaged areas in failure of infrastructure.	Case studies on impact of climate change on failure of engineered infrastructure in socioeconomically disadvantaged communities.	Discussion of how coastal urban infrastructures and services can be made less vulnerable. Assignment on how socioeconomic situation or marginalization of a community impacts vulnerability to climate change.

6	Bias and lack of inclusivity as a threat multiplier; Future solutions and best practices	Bias, lack of inclusivity on design teams (“missing voices”), and lack of diversity in stakeholder feedback, as “threat multipliers” for engineering failure.	Readings from “Technically Wrong” by Sara Wachter-Boettcher and “Race after Technology” by Ruha Benjamin; Readings on bias-related failure in medical devices and software; Interviews with two industry professionals of color, both of whom are alumni and have been active in NSBE as well as active in recruiting diverse students to the engineering profession.	Research an example from readings of bias or lack of inclusivity as a threat multiplier for engineering failure. Also describe how the risk (through better design or technology deployment) of such a failure can be reduced, and whether this failure has been responded to. Students are also offered extra credit for additional examples. Students are also asked for a reflection on the two recorded zoom interviews with alumni.

Table 1: Redesigned learning modules for ESG 201: Learning from Engineering Disaster

As indicated, topics and assessment of learning related to the impact of bias, lack of inclusivity, and lack of diversity in stakeholder input have been integrated throughout the course. As a result, students will be exposed to the importance of these topics multiple times, and will be asked to consider the impact of these factors on a range of critical steps in the engineering design process.

<u>Outcomes of learning modules in the current course:</u>

As described above, diversity, ethics, inclusivity and justice aspects are being integrated into multiple learning modules of the course on Learning from Engineering Disaster. The current course offering has 150 enrollees (online), of whom 58 are seniors, 65 are juniors, 22 are sophomores, and 5 are freshman level. These students represent 28 separate majors, including all areas of engineering, 11 arts and sciences majors, 10 humanities majors and several health sciences majors. It is of interest that in the discussion forum for the first introductory learning module (completed during the first week), only 5% (8 out of 150) of students cited an example, while defining engineering disaster, with causes or impact related to bias, lack of diversity, or increased risk in marginalized communities. This will be contrasted with a survey to be conducted at the end of the course to help determine the impact of the course on student views and consideration of critical values for engineering success.

Content in the second module, specifically addressing the role of ethics and values in engineering design, does begin to focus on issues of diversity and inclusivity (as per Table 1). Following lectures and readings on the engineering design process, including a chapter on Value Sensitive design, one of the essay questions now asked is: “How can a value of inclusivity or diversity be integrated at each stage of the engineering design process?”

Most common student responses included identifying the need for recognizing and integrating the needs of a diverse and inclusive group of stakeholders (90% of students include this concept); including all voices in gathering of pertinent information for concept generation (90%); making sure that concept selection responds to needs of diverse groups, including choosing designs for accessibility and usability by the differently abled (80%); identifying unintended consequences of design which can lead to bias and failure to meet the needs of a diverse population (75%); testing of prototypes involving people from a wide variety of backgrounds and demographics (70%); accessibility testing (70%); studies of the impact of prototypes, etc. in real-world communities of various types (55%); recognizing internal biases (racism, ageism, sexism) in design teams and design companies (55%); inclusion of a range of socioeconomic status in design considerations (50%); analysis of biases inherent in design constraints (50%); and accounting for socio-political considerations in design which impact cost, availability, etc. (50%).

The third module continues to address these topics, and adds content specifically focused on bias in design of technologies and location of high-risk facilities in marginalized or socioeconomically disadvantaged community (which are often areas with large minority populations). An essay assignment included a question asking students to report on impact on "vulnerability" of infrastructure due to location in socioeconomic disadvantaged or marginalized communities (as well as how the presence in those communities can increase the "cost "of failure). Student responses are varied, but show a clear learning gains in understanding how demographics and socioeconomic conditions enhances vulnerability to failure. Specific examples chosen by the students include: construction of failure-prone buildings in poorer rural areas of Pakistan (leading worse living standards in general); substandard and failing buildings and services in a disadvantaged area of New York City; the devastation from Hurricane Katrina in disadvantaged areas of New Orleans with a large minority population; failure of the water sanitation system in Rosario de Tesopaco, a rural community in northwest Mexico; the Flint, Michigan water crisis; and siting of a hazardous waste treatment facility in a poor area of north Carolina with a large minority population.

The fourth module, as noted in Table 1, does not specifically address issues of diversity and inclusivity as it is mostly a technical module discussing a few historical failures which can be linked to laboratories demonstrations of texting of materials. For example, a site visit and interview with the director of the Hindenburg crash site museum is coupled with a lecture on the disaster and with laboratory demonstrations (conducted by the author) of electron microscopy and chemical spectroscopy performed on actual samples from the Hindenburg wreckage to identify the cause of failure. We plan to integrate diversity and inclusivity issues into this module in the future (based on a current laboratory study on the impact of skin color on the accuracy of pulse oximeter readings, for example). Student results from the final two modules were not available at the preparation of this manuscript, but will be presented at the ASEE annual meeting and will be added to a future version of this study. However, preliminary informal feedback from students concerning the two interviews with alumni (both currently successful engineers at major companies – Boeing and Blue Origin), has been extremely positive. In particular, many students find these interviews to be inspiring, no doubt enhanced by the fact that both individuals (one male and one female) are persons of color and both were leaders with the National Society of Black Engineers at students.

Conclusions:

While this is a project “in progress”, and limited data is available at this time, the course design and revision process and preliminary results indicate that our course on Learning from Engineering Disasters (and failures) can provide an ideal vehicle for the teaching of issues of diversity, ethics, inclusivity and justice in the engineering design process. Further, the adapted ADDIE process in general, and in particular the excellent comment from an external advisory group of faculty who represent diverse viewpoints and backgrounds, has been extraordinarily valuable in the course redesign process. Their contributions will no doubt continue to be extremely valuable as we evaluate our first redesigned course offering.

Acknowledgements:

We gratefully acknowledge the support of the College of Engineering and Applied Sciences, the Department of Materials Science and Chemical Engineering, and the Center for Inclusive Education at Stony Brook University. In addition, we acknowledge support from the National Science Foundation Division of Engineering Education and Centers REU grant 1950645 and past support in encouraging the author to continue to pursue pedagogical explorations and in helping to support dissemination of our results.

References:

(1) Kathleen Lobb, “Workforce Blog: Equity in Engineering Matters”, ASME, October 4, 2021; accessed at https://www.asme.org/topics-resources/content/workforce-blog-equity-in-engineering-matters

(2) ASME, “Diversity, Equity, and Inclusion in the STEM Workforce”, public policy position paper, 2021; accessed at https://www.asme.org/getmedia/29bbd12e-877b-4d9c-a3f1-dfc24555043a/ps21-06-de-i-stem-2021.pdf

(3) Harriet Hartman,Tiago Forin, Beena Sukumaran, Stephanie Farrell, Parth Bhavsar, Kauser Jahan, Ralph Dusseau et al. "Strategies for improving diversity and inclusion in an engineering department." *Journal of Professional Issues in Engineering Education and Practice* 145, no. 2 (2019): 04018016.

(4) M.E. Matters, C.B. Zoltowski, A.O. Brightman, and P.M. Buzzanell, "An Engineering Faculty and an Intention to Make Change for Diversity and Inclusion: Creating Sustainable Change Efforts". *2021 CoNECD*, https://par.nsf.gov/biblio/10317482.

(5) Mehdiabadi Hedayati, Jordan James Amir , and Vanessa Svihla. "Ethical reasoning in first-year engineering design." In *Proceedings of the ASEE 126th Annual Conference and Exhibition*. 2019.

(6) Dianne Grayce Hendricks, Camille Birch, and Celina Gunnarsson. "Exploring the Interplay of Diversity and Ethics in an Introductory Bioengineering Course (Work In Progress)." In *2018 ASEE Annual Conference & Exposition*. 2018.

(7) Renée Pellissier, Faye Siluk, Claudia Flynn, and Marwan Kanaan. "Approaching Equity, Diversity, Inclusion, and Social Justice Education as Imperative to Engineering Curricula." *Proceedings of the Canadian Engineering Education Association (CEEA)* (2022).

(8) Dixie Abernathy, “ADDIE in Action: A Transformational Course Redesign Process”, Journal for the Advancement of Educational Research International, v13 n1 pp 8-19 (2019).
(9) Kaye Shelton and George Saltsman. "Applying the ADDIE model to online instruction." In *Instructional design: Concepts, methodologies, tools and applications*, pp. 566-582. IGI Global, 201.
(10) Gary Halada, “Teaching by Disaster: The Ethical, Legal and Societal Implications of Engineering Disaster”, Proceedings, American Society for Engineering Education, Middle Atlantic section ASEE Annual Conference, October 15-17, Villanova University, PA (2010).
(11) Gary Halada, “Learning from Engineering Disasters: A Multidisciplinary Online Course”, Paper ID #20401, Proceedings, American Society of Engineering Education Annual Conference and Exposition, Columbus, Ohio, June 25-28, 2017 (2017).
(12) Brian Christian, *The alignment problem: Machine learning and human values*, WW Norton & Company, 2020.
(13) Sara Wachter-Boettcher, *Technically wrong: Sexist apps, biased algorithms, and other threats of toxic tech*, WW Norton & Company, 2017.
(14) Ruha Benjamin, *Race after technology: Abolitionist tools for the new Jim code*, (2020).
(15) Britta Neugaard, “Halo effect”, retrieved October 08, 2020, from https://www.britannica.com/science/halo-effect