The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #44129

Integrating Community-Engaged Research and Energy Justice in Design Pedagogy: Reflections on a First-Year Undergraduate Design Course

Prof. Aditi Verma, University of Michigan

Aditi Verma (she/her) is an Assistant Professor in the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan. Aditi is broadly interested in how fission and fusion technologies specifically and energy systems broadly—and their institutional infrastructures—can be designed in more creative, participatory, and equitable ways. To this end, her research group at the University of Michigan works towards developing a more fundamental understanding of the early stages of the design process to improve design practice and pedagogy, and also improve the tools with which designers of complex sociotechnical systems work. She was previously a Stanton Nuclear Security Postdoctoral Fellow at the Harvard Kennedy School's Belfer Center for Science and International Affairs. Prior to her appointment at the Belfer Center, Aditi worked at the OECD Nuclear Energy Agency, her work, endorsed and funded by policymakers from the NEA member countries, focused on bringing epistemologies from the humanities and social sciences to academic and practitioner nuclear engineering, thus broadening their epistemic core. At the NEA, Aditi also led the establishment of the Global Forum on Nuclear Education, Science, Technology, and Policy. Aditi holds undergraduate and doctoral degrees in Nuclear Science and Engineering from MIT. Her work, authored for academic as well as policymaking audiences, has been published in Nuclear Engineering and Design, Nature, Nuclear Technology, Design Studies, Journal of Mechanical Design, Issues in Science and Technology, Bulletin of the Atomic Scientists, and Inkstick. Aditi enjoys hiking with her dog, reading speculative fiction, and experimenting in the kitchen.

Dr. Katie Snyder, University of Michigan

Dr. Snyder is a lecturer for the Program in Technical Communication at the University of Michigan. She teaches design, ethics, and technical communication as social justice in the College of Engineering.

Integrating community-engaged research and energy justice in design pedagogy: Reflections on a first-year nuclear engineering undergraduate design course

Aditi Verma and Katie Snyder

Introduction

The language of engineering is replete with ‘unintended consequences’ as amply illustrated across a number of examples, ranging from the mundane to grave –left-handed individuals struggle with most appliances (scissors, vacuum cleaners, can-openers); car crash fatality rates for women are higher than for men because crash-test dummies (until 2022) were modeled on male bodies[1]; facial-recognition technologies frequently misidentify Black individuals[2]; soap dispensers fail to operate for dark-skinned people (only recognizing light skin tones); the health effects of radiation are characterized for ‘reference man’ (170 cm tall, 20-30-year-old Caucasian male, weighing 70kg). Engineer-designers, implicitly or explicitly, assume a ‘reference man’. Most of us are not reference man, and if ever, will only be reference man for a brief period in our lives. In this way, we engineers effectively design technologies that serve but a few well and poorly serve others, if at all.

The problem becomes even thornier for complex sociotechnical systems –including most energy technologies, especially nuclear. Energy systems have few ‘users’ in the traditional sense but they impact many, many people – both during normal operation and failure. Instead, these systems have stakeholders, or better put, ‘rightsholders’ – individuals who are impacted by the development and use of these systems but seldom have a say in any stage of design. Breaking from this traditional approach, we have developed a new course “ Socially Engaged Design of Nuclear Energy Technologies” for first-year undergraduate students at our home institution. In this paper, we describe the pedagogical philosophy underlying the course and the lessons learned from its first offering in the Fall of 2023. Notably, all sections of this course operate under a design-build-test model and feature, lecture, lab, and discussion sections.

Through the course, students examine positionality, power, and language in the context of socially engaged design. Students write positionality statements before they begin their project work, we provide readings and discussion about social power in the engineering design process, and we examine how language can make information more or less accessible to specific audiences. Course assignments and lectures present ethics and engineering work as necessarily intertwined. For example, students learned the fundamentals of nuclear science and engineering alongside qualitative research methods and completed a community engagement workshop. Additional assigned readings and videos offer opportunities to reflect on user-centered design, the relationship between politics and technology, and the ethics of nuclear weapons development.

Virtual reality technologies were used to learn nuclear reactor design and facilitate the community engagement experience. In their final designs, students worked with community members in a day-long workshop to design main features and exterior components of an imagined nuclear fusion reactor sited in our local community. In their final presentations, every student team noted that engineering design work must include users and stakeholders in the design process to ensure ethical, successful, user-centered designs. Many students commented to us on how their perspective about engineering had changed – away from exclusively centering technical concerns and toward centering the people who might be impacted by engineering processes and products.

Background

Engineering fields writ large embrace positivism, objectivity, and meritocracy [3], [4]. In practice, these values are aspirational rather than being descriptors of the fields. These descriptors efface the politics and values with which designed artifacts, systems, and built environments are imbued, invisibilizing not only preferences and value judgments that go into making design decisions but also invalidating the experiences of people who are poorly served by technologies and systems (because these systems were not designed with them in mind).

Looking specifically at design – it is often depicted in academic textbooks as a process of problem identification, decomposition, solution of the sub-parts of the problem, and solution integration. As with the descriptors above, this is more an aspiration for what design should be and not what it actually is – which is messy, iterative, logical but not always, and deeply human. This is not to say that design itself is inherently flawed. It is not. However, it is far from the sanitized process presented to students of the field.

Finally, design, particularly in the context of complex, sociotechnical systems, is presented as being depersonalized and largely stripped from context, with little consideration of the preferences of the people who might live around these systems and facilities and be impacted by their presence for decades. While these logics may have served the field for decades, we are of the view that moving forward, particularly in the nuclear (and other energy) field(s), these logics are going to become increasingly impractical. This is because of the growing interest in smaller scale (eventually perhaps even personalized) energy systems sited in much greater proximity to people and communities than have the systems of the past. As a result, there is a growing interest from communities that might host these systems to shape key decisions about how these systems and facilities are designed. Despite this shift, students are given little to no formal training on how to frame design problems, practice empathy, and approach these problems from the perspective of others, as well as how to systematically gather input from the many individuals who stand to be impacted by the design and operation of a new system (energy or otherwise).[5], [6] It is our intent through this course to address these gaps in design education.

Course structure and novelty
Our course is offered to first-year undergraduate students in the College of Engineering at our home institution. All incoming first-year undergraduate students take a variation on Introduction to Engineering, with each department in the College offering its own section of the course. Our section is called “Socially Engaged Design of Nuclear Energy Technologies.” In its first offering in Fall 2023, the course had 38 students. Students from any engineering major can take this course, meaning that some were nuclear-interested but many were planning to major in other disciplines. As is typical of many schools right now, we had a significant number of students interested in computer science and engineering. But a wide range of engineering fields were represented in our course.

All Introduction to Engineering courses in the College of Engineering are design-build-test courses, as is ours. The project with which students in our course are tasked is the design of a hypothetical fusion energy facility in collaboration with community members from Southeast Michigan. A week in the course comprises two lecture sessions, a lab session, and a discussion section as shown in Figure 1 below.

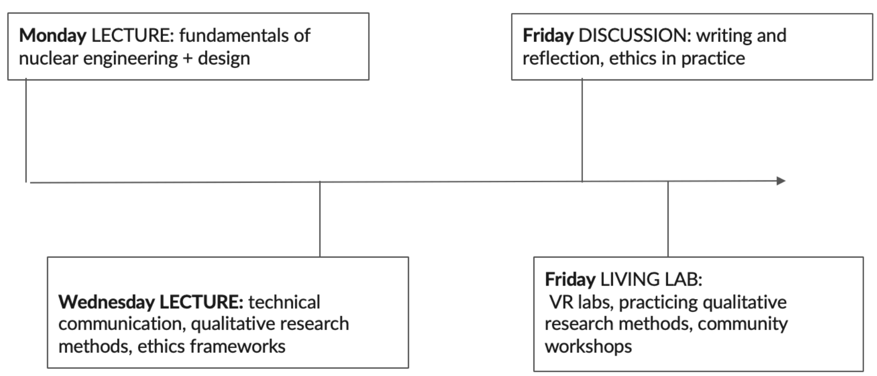

Figure 1. A week in the course, ENGR 100: “Socially Engaged Design of Nuclear Energy Technologies.”

What is novel about this course?
The course marks a departure from traditional engineering design courses in at least the following five ways:

Engineering as sociotechnical: Rather than present engineering primarily as technical work, we present it to the students as being fundamentally *sociotechnical.* In other words, we ask students to examine the social implications of engineered products and processes. We ask them to reflect on the ways engineering shapes social life, for better and for worse. As noted in the introduction, much of the work in our course invites reflection and discussion and pairs these components with technical learning and application. For example, as students complete the lab protocol where they use VR tools to learn about nuclear reactor design, we include reflective prompts, asking them to note what ideas (concerns, questions) are coming up for them as they are learning about the reactors, and also evaluate how new and emerging reactor technology might be received by people in their hometowns. As another example, we took students on a “deep time” journey, asking them to reflect on how today’s nuclear technologies might impact future generations, including many thousands of years in the future. Students struggled to think beyond the next 100 years, but we wanted to ignite in them a curiosity about the future; this as a way toward more sustainable and ethical energy system design.

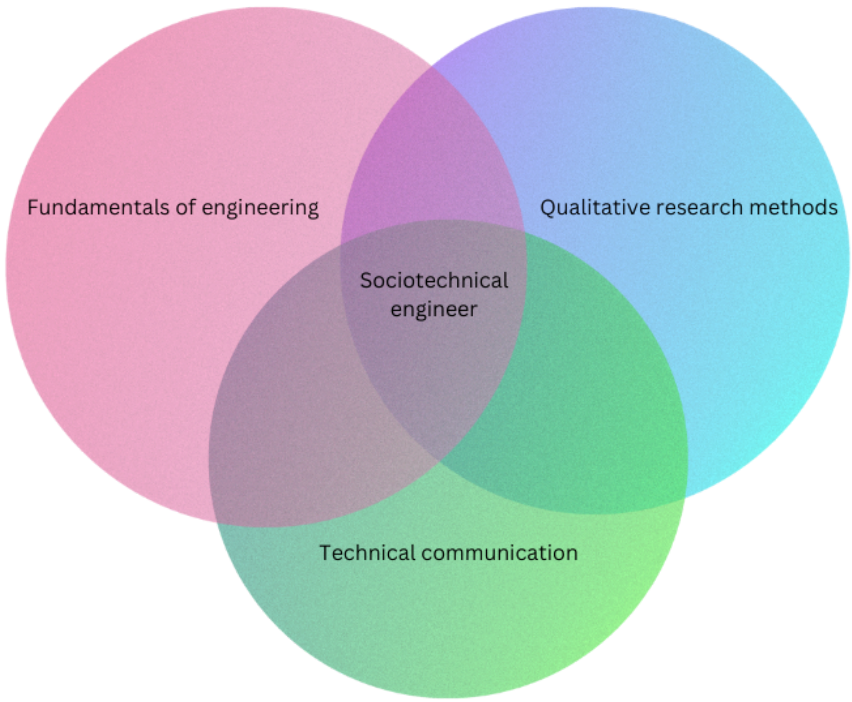

Figure 3. What it means to be a sociotechnical engineer

Entangling engineering and technical communication lessons: Each section of this introductory engineering course features two co-instructors: one from engineering and one from technical communication. In some courses, these disciplines are taught in parallel, but our course represents an emerging trend in integrating the communication and engineering work together so they are not separable.. Over the semester, students learn the fundamentals of nuclear engineering (nuclear physics, the science and engineering behind fission and fusion systems, nuclear waste and its management, and nuclear accidents), alongside technical communication (effective oral and visual communication and design, frameworks of ethical decision making), and qualitative research methods (how to carry out interviews, how to code qualitative data, how to carry out observations). We view communication as central to engineering work and encourage students to be deliberate and mindful about their communication practices in the course.

Teaching nuclear fission and fusion reactor design VR: In addition to learning about nuclear energy systems in lectures, students explore and immersively experience these systems in VR environments. For the course, we have developed system and facility-level models of both fission and fusion energy facilities. System-level models offered an expanded view so that components were separable and students could apply component labels to support their learning. Facility-level models operated from a first-person video game perspective, allowing users to explore the space and also have a strong sense of facility scale. Students recorded video tours of these facilities and our objective, next year, is to share these videos with community members and bring them into the VR lab space to explore the models in person. The hope here is that we would be able to better facilitate community-engaged design conversations if community members can learn a bit about the reactors in the VR.

Inviting creativity and divergent thinking: Students practice creative, divergent thinking through multiple in-class workshops. As preparation for their workshops with community members, students completed several in-class workshops together to practice creativity and divergent thinking. In engineering work, we ultimately need to converge on a single idea and move forward with the engineering design process. But we wanted students to find value and comfort in inviting divergent thinking as a way to explore creative possibilities that might be overlooked, seem unconventional or even impossible. For example, through a series of prompts, students worked individually and collaboratively in Mural to explore ideas related to nuclear reactor siting and facility design.

Teaching collaboration in the context of relational responsibility: Critically, students learned how to engage respectfully with community members and work collaboratively with them to design a hypothetical energy facility. In preparation, they researched and wrote about the philosophical concept of relational responsibility or the idea that each person has a responsibility to others, to act ethically and respectfully. After students had completed their in-class workshops, students had a chance to work with 22 community members virtually and in person (community members opted into the project by filling out a form in response to advertisements on social media and print - we aimed to collect a diverse sample of participants). We completed two two-hour virtual workshops where students were primarily observers and they learned about community members' perspectives about emerging nuclear fusion technologies and the imagined possibility of siting a fusion reactor energy system. Using the qualitative methods they had learned in class, students took notes, asked key questions, and wrote about their observations and experiences. In the final day-long, in-person workshop, students worked with community members to determine design features for this same scenario: an imagined nuclear fusion energy facility in their community. They worked together to determine design criteria and ultimately used AI image-generators to visualize an energy facility prototype.

A timeline of the topics covered in the course during lectures, labs, and discussion sections is shown below. (This is a representative but not exhaustive list)

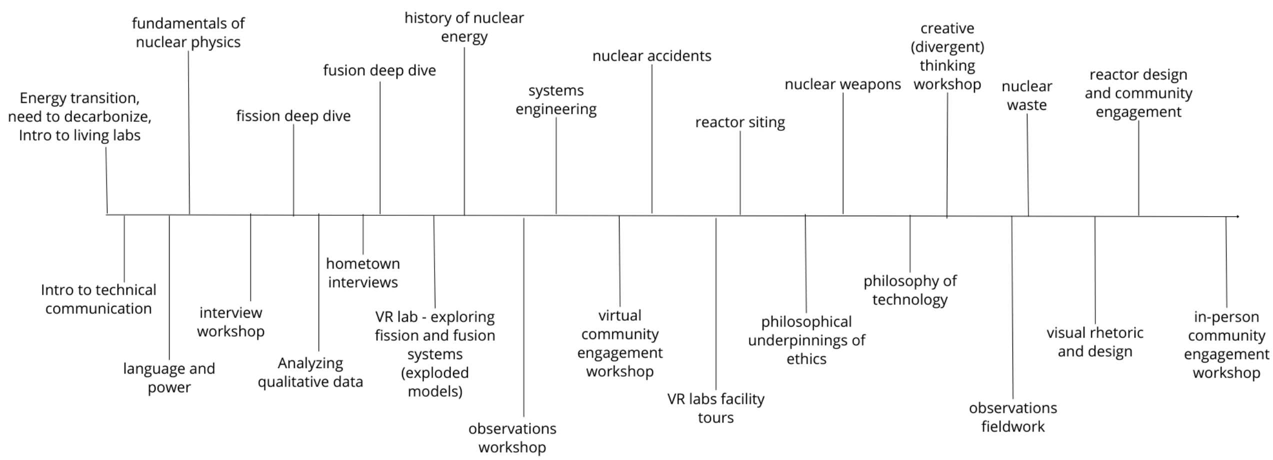

Figure 2. A timeline of topics covered in our course – Socially Engaged Design of Nuclear Energy Technologies

Conclusion: Reimagining engineering expertise

In its broadest sense, a central goal of this course is to reshape the very nature of what it means to be an engineer – by offering students the fundamentals of nuclear engineering alongside training in technical communication and qualitative research methods to create a new kind of sociotechnical engineer (depicted in Figure 3).

We recognize that while our course presents engineering as being fundamentally sociotechnical, many others in the College of Engineering do not. This may lead to a cognitive dissonance for the students who, on learning and practicing engineering design in other course contexts, might find it to be very different from what they learned in our course. In their closing presentations, many student teams expressed a conviction that they would always, in future design efforts, seek to engage with those who are likely to use and be impacted by their designs. While we applaud this aspiration, the onus should not be on the students to create space for this type of engagement. With this in mind, we are exploring opportunities for further embedding sociotechnical considerations into other courses. This inclusion is already underway for many courses in the Nuclear Engineering and Radiological Sciences Department.

References

[1] C. C. Perez, *Invisible Women: Data Bias in a World Designed for Men*. Abrams, 2019.
[2] J. A. Buolamwini, “Gender shades : intersectional phenotypic and demographic evaluation of face datasets and gender classifiers,” Massachusetts Institute of Technology, 2017. Accessed: Feb. 08, 2024. [Online]. Available: https://dspace.mit.edu/handle/1721.1/114068?show=full
[3] E. A. Cech, “The (mis) framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers’ ability to think about social injustices,” *Engineering education for social justice: Critical*, 2013, [Online]. Available: https://link.springer.com/chapter/10.1007/978-94-007-6350-0_4
[4] C. Seron, S. Silbey, E. Cech, and B. Rubineau, “‘I am Not a Feminist, but. . .’: Hegemony of a Meritocratic Ideology and the Limits of Critique Among Women in Engineering,” *Work Occup.*, vol. 45, no. 2, pp. 131–167, May 2018.
[5] A. Verma, “Towards Equitable design and development of nuclear energy infrastructure,” Fastest Path to Zero, RISE3 (Research Impacts on Social Equity and Economic Empowerment) Fact Sheet series , forthcoming 2023.
[6] Energy Communities Alliance, “Why Local Governments and Communities Support New Nuclear Development,” 2022.