Connecting Campus and Community: Applying Virtual Reality (VR) Technologies to Facilitate Energy Justice and Emerging Technology Literacy

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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.

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Introduction

The history of energy technology development (including nuclear energy) demonstrates that the process of designing, developing, and using energy technologies creates significant inequities – extractive and waste management facilities are typically sited around communities of color and low-income communities whereas the power-producing facilities are sited around affluent (predominantly white) communities.[1] In neither case do communities actually have a say in the type of facility being built in their community and seldom have a say in the decision to even site that facility. If we are to equitably develop our energy systems of the future, there is an urgent need to reverse this worrying trend. To that end, we aspire to train future developers of nuclear energy technologies – fission and fusion – to acknowledge and incorporate social, ethical, and environmental considerations in their engineering practice as well as seek direct community input in the early stages of design. In this paper, we report on our development and use of virtual reality (VR) models of nuclear energy systems as immersive tools for learning and community engagement in a "living lab" [2] style format.

Background

It is important to recognize that while extended and virtual reality technology offers significant potential, it is not without its limitations. Early proponents of VR touted its ability to foster empathy and challenge systemic biases by enabling users to view perspectives vastly different from their own. However, recent research indicates that while VR can indeed support these objectives [3], its effectiveness is not guaranteed [4]. To address these complexities, our approach to developing and using VR is guided by socially engaged design and equity-centered engineering frameworks. Within these frameworks, students will be able to pursue objectives aligned with our college's Experiential Learning Initiative. These include honing communication skills, cultivating empathy, promoting cultural awareness, exploring ethical considerations, fostering continuous learning, and encouraging teamwork in virtual environments. With intentional design and incorporation, VR has the potential to enrich student learning experiences by providing immersive opportunities that are otherwise inaccessible in traditional classroom settings. Moreover, it has the capacity to create more inclusive learning environments that cater to the needs of a diverse student body.

Methods
The section below describes our methods and the novel aspects of our approach to bringing virtual reality and socially engaged design into a specific course, "Introduction to Engineering: Socially Engaged Design of Nuclear Energy Technologies.." We developed this course in the spring and summer of 2023, with the inaugural section running in Fall of 2023.

Our course: Introduction to Engineering
"Introduction to Engineering" is taken by all first-year undergraduate students in the College of Engineering at our home institution. Different departments offer different sections of this course, with each section having up to 80 students. All sections are project-based, operating on a design-build-test framework. We created our section with the intent to teach students the importance of engaging with publics and communities as part of the engineering design process. While such engagement is increasingly becoming the norm for the design of smaller, and less complex systems, the designers of complex sociotechnical systems – transportation and energy systems being two key examples – seldom engage with communities during the process of technology development. This is especially the case for energy technologies and facilities. These systems have but a handful of 'users' in the traditional sense in that they have operators, but they stand to impact many – both positively and negatively – irrespective of how they function (poorly or well). These individuals – communities who live around the facility – have the right to provide input to the design and development of these systems. For this reason, we refer to them as 'rightsholders' [5]. (We deliberately eschew the use of the term 'stakeholder' because of its colonial origins).

Our course centers around the design of a hypothetical nuclear energy facility to be built in Southeast Michigan, with students closely working with community members to design the hypothetical facility. Figure 1 below shows how the design-build-test cycle is completed in the context of a 'living lab' with VR being used as a tool in that process. We developed a living lab in our course, a space where design work can be developed and tested in real contexts with actual users, to facilitate community engagement in the design process.

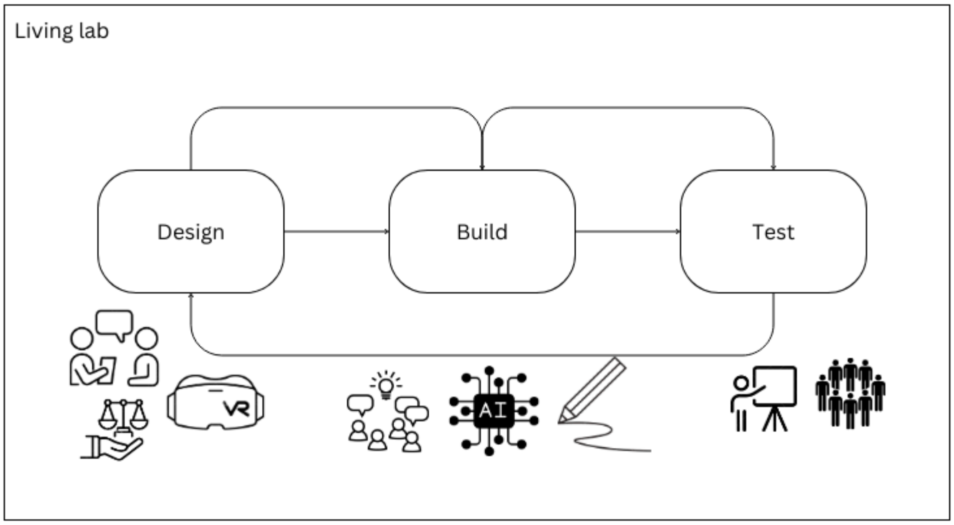

Figure 1. Integration of VR into a design-build-test course

Novel aspects of the course: VR models of nuclear energy systems

In our course, we have used VR models of nuclear energy systems – fission and fusion – to immersively teach the students about these systems – including their scale, scope, and complexity. For first-year undergraduate students who have not taken advanced (or at this point, any) courses in nuclear engineering (such as reactor physics, thermal hydraulics, and materials under extreme radiation environments), these models are an invaluable teaching and learning tool allowing the students to experience and explore systems in a manner that would not otherwise be possible as these systems are so difficult to access.

Two types of nuclear energy system models were built for this course. These include a set of cross-section models (Figure 2) that enable the students to closely examine every part of the systems. Students can also disassemble these models, pull apart the components, and then fit them back together. Additionally, these models are designed to have a labeling feature (also shown in Figure 2) that allows students to learn about the different system components as well as their functions.

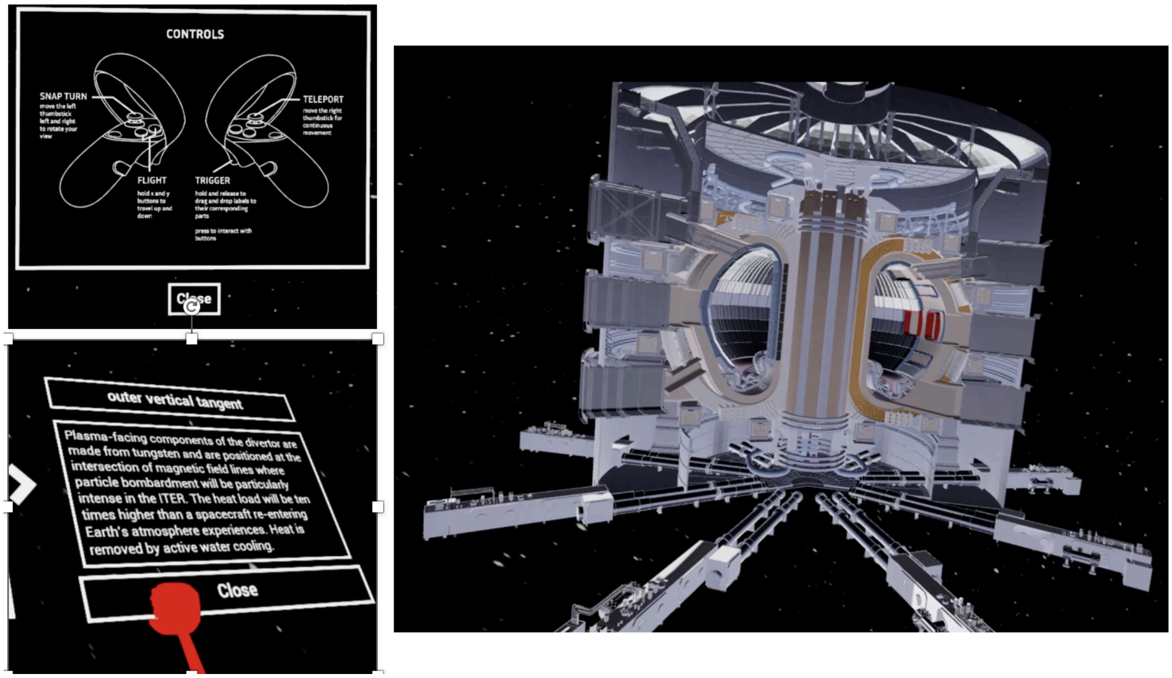

Figure 2. A cross-sectional view of the tokamak and the labeling mechanism.

A second set of models are facility-level models (as shown in Figure 3) set up as first-person player video games. Students exploring these models can walk around the entire energy facility, explore the layout, and develop an understanding of how the facility fits into its surroundings.


Figure 3. Facility-level VR models developed for the course. The image on the left shows the facility-level model for the fission facility. The image on the right shows the facility-level model for the fusion energy facility.

Use of the VR models in class

The models have been used in two main ways as part of the course thus far: exploring the nuclear energy systems in virtual reality and recording tours of the energy facilities for other people who may not have access to the lab. The models are made available to the students during their lab sessions which take place on Fridays. Students also could schedule additional lab time to work with the VR models as needed.

Exploring the system
In an initial lab session, students explored the cross-sectional and labeled the components. In a subsequent session, students explore the facility-level models and record their observations and experiences of touring a nuclear facility in a VR environment. Many students shared in written reflections that they were surprised by the complexity of the reactor designs, and impressed with how well this complexity was made visible in the virtual environment. At least one student (out of 38) experienced a headache that they attributed to time spent in the VR headset, but most were pleased with this approach to learning about nuclear reactor design.

Recording tours of the facility
In a third lab session, students were tasked with recording brief tours of the nuclear energy facilities using the screen recording feature. To do this, students first made key decisions about their audience for the tour, where the tour would start and end, and what the highlights of the tour would be. Based on these key decisions, students created a script which they then used as part of the tour. Many students in their term presentations observed that they had shared their facility tour videos with friends and family members as a way to show them what they were learning in their first semester at university.

Offering tours of the facility
Though this has not yet been implemented, our next intended use case for the VR models is to use them to support community engagement and participatory design. As part of the next course offering, we will invite community participants to take tours of the nuclear energy facility before engaging in a participatory design workshop. We anticipate some challenges in terms of scheduling and making this opportunity accessible to a wide range of community members. However, we aim to offer multiple days and times. In all cases, we will compensate participants for their engagement.

Tools for Participatory Design
We also intend as part of the next iteration of the models, to build customizability into the VR experience, such that users can make changes to the facility design (aesthetics, layout, choice of materials) while they are exploring the facility. In this way, we intend the VR models to be tools not only for immersive learning but also for participatory design. The first phase of these model revisions will take place in Summer 2024 with an aim to implement customizable models in the Fall 2024 semester.

Conclusions
The first offering of our course concluded in December 2023. We are embarking on analyzing the vast amount of knowledge and data generated through the course. Our immediate next step is to analyze the three student lab assignments for which the students made use of the VR models to better understand the different ways in which the VR models supported (or did not) the

development of an immersive understanding of nuclear energy systems. We hypothesize that engineering systems need not be unknowable until engineering fundamentals are mastered through various advanced and introductory courses. We are of the view that an immersive understanding of these systems can precede analytical understanding and is sufficient to support rudimentary system design. With this immersive understanding, not only can early-stage undergraduate students but also community members (particularly from communities who might one day host an energy facility) offer credible input to the design of the facility in question.

Our longer-term objective, as described above, is to update the VR models both to make them customizable (as noted above) as well as to expand our library of VR models to include not only nuclear but also other kinds of low carbon/clean energy systems.

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