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Designing for Climate Resilience and Adaptation with Electric Power Systems in Engineering Design Teams

Prof. Courtney Cole, The Pennsylvania State University

Courtney Cole is an Assistant Teaching Professor of Engineering at Penn State New Kensington, where she teaches a mix of fundamental courses in mechanical and industrial engineering. Courtney previously worked in the commercial nuclear energy industry at GE Vernova, supporting the BWRX-300 project prior to returning to academia. Most of her work now focuses on working with industry to apply various tools in the classroom environment, such as the tools developed under the Electric Power Research Institute's Climate Resilience and Adaptation Initiative (READi). She also works with Climate READi as an affinity member, providing feedback on research publications and tools while also attending annual meetings and connecting with people in the utilities industry.

Laura E Cruz, Penn State

Laura Cruz (Ph.D, UC Berkeley 2001) is an Associate Research Professor for Teaching & Learning Scholarship with the Schreyer Institute for Teaching Excellence at Penn State. She previously served as the director of two Centers for Teaching and Learni

Work in Progress: Designing for Climate Resilience and Adaptation with Electric Power Systems in Engineering Design Teams

Abstract

Although much of the discussion in the climate change space focuses on mitigation and more specifically, sustainability, there is a lack of discussion on climate resilience and adaptation. From areas such as insurance and the utilities industry, climate resilience and adaptation have become more of a discussion topic in recent years. How could an engineering design course be redesigned to include this side of the climate change issue in view while integrating industry-based tools that help engineering design students apply findings from the electric power industry to their designs? This paper seeks to address this question through an analysis of behaviors and attitudes of first-generation and non-first-generation students towards group projects focused on climate resilience and adaptation, as well as the perceived usability of tools used to gather information on climate vulnerabilities and adaptations. This goal is achieved through using a design challenge focused on designing for climate resilience and adaptation in the electric power industry (which focuses on generation, transmission, and distribution) using findings from the Electric Power Research Institute's Climate READi initiative as a means to train students how to design more effectively for electric power systems, as well as take a more creative approach to their designs. The findings from this research will be applied to develop a validated scale for analyzing behaviors, attitudes, and knowledge on climate adaptation and resilience that will be applied on a larger scale.

Keywords

Climate resilience; climate adaptation; electric power systems; energy; generation; transmission; distribution; digital tools; usability; engineering design teams; sustainability; climate change; Design Methods Frameworks & Mindsets

Introduction

In 2012, the United Nations challenged the world to achieve 17 sustainable development goals by the year 2030. It is widely acknowledged, too, that much of the success of the strategic and collective endeavors to reach these goals relies on the work of engineers. In a 2023 update, the UN reported that progress towards the global sustainable development goals (SDGs) is "badly off track" and called for "the transformation of education" as the starting point for "reignit[ing] our efforts to achieve the 2030 Agenda" [1].

This call to action applies to engineering education. Throughout much of its history, engineering education has focused on teaching students the knowledge and skills they need to design solutions to complex technical challenges. Because it is an applied discipline, too, the pedagogy has shifted towards project-based learning, in which students apply what they have learned to real-world cases, at times even working with real-world clients [2]. As more of those clients adapt the standards of Corporate Social Responsibility (CSR) and the Triple Bottom Line (environmental, social, and economic factors) (TBL), there is now an increasing need for future engineers to learn more than just hard and soft skills, but also to engage in cross-disciplinary systems thinking and to integrate multiple dimensions of global sustainability into their designs.

Starting in 2012, ABET has recognized sustainability as a constraint, or set of parameters, within the core function of engineering design. Because sustainability thinking is complex, the primary locus for students engaging in sustainability-focused engineering design has been at the upper division level, such as through a capstone project and/or senior design course [3, 4]. Emerging studies of these projects suggest, however, that one project is insufficient to reach the desired sustainability outcomes, which has contributed to calls for integrating sustainable design principles and projects across the engineering curriculum (regardless of focus area), starting as early as the first year [5-9]. As Abd-Ewahed & Al-Bahi [10] note, "[multiple] Engineering design courses can increase the sustainability practices of future engineers by creating and implementing their designs considering the sustainability TBL and measuring sustainable performance indicators and metrics (p. 634)."

Because sustainability-focused engineering design courses at the lower level are relatively new, comparatively little research has been done to identify the indicators and metrics indicated. As a baseline, engaging in this kind of curricular scaffolding requires identifying (and assessing) stages of development that are appropriate for each course level. This may be especially important in introductory or first-year courses, as these courses serve as entry points to engineering degree programs (as well as future careers in the field). At the same time, such courses are likely to be the most challenging to scaffold, as they are perhaps the furthest removed from real-world ready mastery, especially in the case of higher-order thinking skills such as integrative learning and systems thinking [11].

One potential strategy for scaffolding sustainable design in engineering education is to shift the emphasis of student projects from climate mitigation to climate adaptation. The distinction has arisen from climate sciences, in which mitigation refers to large-scale, multi-national efforts to reduce the harmful effects of climate change; and adaptation refers to more localized efforts that seek to prepare local communities to navigate the dangers of climate change [12, 13]. Within engineering, climate adaptation has seen attention with applications mostly focused on built infrastructure [14-16]. Climate adaptation is typically coupled with climate resilience, which is defined as the capacity of interconnected systems to cope with a climate change event or trend through responding in ways that maintain their essential function, identity, and structure [17]. In this sense, designing for climate adaptation with resilience in mind can help designers create systems that can withstand hazards such extreme weather events and climate change for years to come.

To date, the majority of project-based learning in engineering design has focused on mitigation-based approaches. The rationale for a shift towards climate adaptation is based on the hypothesis that localized projects will reduce the perception of abstraction [18, 19], strengthen a sense of agency or purpose [8, 20], and increase the perceived relevance [21] of sustainable design projects, making them better suited for first-year engineering students.

The present study seeks to contribute to research and practice in engineering education by assessing the outcomes of a redesigned, first-year engineering design course which integrates a real-world project focused on climate resilience and adaptation. Specifically, this course integrates the use of the Vulnerabilities & Adaptation Strategies Inventory (VASI) [22], in which its perceived usability is investigated alongside survey data on attitudes and behaviors towards team-based projects that focus on climate resilience and adaptation. The VASI tool was developed under the Electric Power Research Institute (EPRI)'s Climate Resilience and Adaptation Initiative (Climate READi) as a repository of known information on physical risks to infrastructure across generation, transmission, and distribution. The tool identifies vulnerabilities due to hazards such as extreme weather events and climate change (e.g., wildfires, flooding, and increased temperatures). In addition to detailing vulnerability functions, the VASI tool also identifies adaptation strategies for various electric power systems and their subsystems and/or components, as well as any lack of adaptation strategies. As one of the intended uses of this database serves as a "baseline for site-specific system planning," [22], it is an appropriate means for students to gather accurate information surrounding climate adaptation strategies and known issues of various electric power systems. While this tool in particular has yet to be used across other areas of engineering education, its intended purpose is to provide practitioners (including engineers working in the utilities industry) with information to develop safe and resilient designs that can withstand extreme weather events and climate change for years to come. Coupled with the Climate READi Compass [23], these tools provide both students and practitioners alike with a starting point for understanding how components of risk (i.e., hazard, exposure, vulnerability, and response) can impact electric power systems.

Aside from using a cornerstone engineering design course to introduce students to complex issues surrounding electric power systems and climate adaptation, the study happens to take place at a small commuter campus. While some studies indicate that commuter status does not necessarily degrade engagement levels [24], campuses such as the one in this study tend to serve more first-generation students [25], which is important to consider as prior research has shown that first-generation students enrolled in STEM programs tend to experience imposter syndrome, which occurs when an student feels that they may be perceived as incompetent [26]. We included first-generation and non-first-generation students for comparison across both analyses focused on the VASI tool as well as the attitudes and behaviors towards this team-based project to understand if this trait could influence results to any extent.

In addition to the struggles that first-generation students may face, these students at smaller commuter campuses are faced with a new challenge: widespread campus closure announcements. Prior work has indicated that campus closure announcements can degrade students' sense of belonging and contribute to feelings of exclusion based on institutional decisions [27]. Although not a focus of this paper, this study was conducted with the last incoming class enrolled at this campus. While the sample size of this study is small, this study provides a foundation for future research in the area of designing for climate resilience and adaptation with electric power systems.

Methodology

Participants

To answer the research questions, a pilot study was conducted over the course of a semester in a class with 25 students. Undergraduate students in the enrolled in a four-year engineering program at any Penn State campus are required to take a first-year cornerstone engineering design course. The students enrolled in this single section of this course at Penn State New Kensington, a small commuter campus that is part of the Penn State system, were chosen as participants and had the option to consent to having their data used for research. Team sizes ranged between 4 and 5 students per team. Students were allowed to self-select their team members.

The Instrument

This descriptive intervention study approved by the Institutional Review Board (IRB) at The Pennsylvania State University utilized an electronic survey, which was distributed to students via the institutionally-owned Qualtrics. A member of the research team who is not the instructor sent out a link to the pre-survey just prior to the start of the design project (at the tenth week of the semester) and to the post-survey shortly after the design project ended, near the end of the regular 15-week academic semester. Students were provided with low-stakes extra credit for completing each iteration of the survey. The overall participation rate was 96% (24 out of 25).

The survey instrument consists of two previously-validated scales, each utilizing a five-point Likert scale (*5=strongly agree, 4=agree, 3=neither agree nor disagree, 2=disagree, and 1=strongly disagree*) unless otherwise specified:

- The 10-item System Usability Scale (SUS), a widely used (in both academics and industry) scale for perceived usability [28], in this case, of the VASI tool on the EPRI website
- The Intrinsic Motivation Inventory (IMI), a widely used instrument that conceptualizes motivation through self-determination theory [29, 30]. For this study, the task-specific version of the IMI was instrument was used with three subscales: interest/enjoyment, pressure/tension, and value/usefulness (12 items).

Each survey also consisted of one open-ended question items, asking students to explain their choice of projects (pre-survey) and role in the project (post-survey); and three demographic questions (intended major, first-generation status, gender identity).

Scaled survey items were assessed using descriptive statistics (mean, median, frequency). Pre- and post- responses were compared using paired t-tests for all questions; Mann-Whitney tests were used for comparisons between demographic groups (e.g., first-generation students and non-first-generation students).

The Intervention

Prior to the start of this design project, students were introduced to a series of lectures that focused on other fields within engineering and guest speakers from industry that focused on career preparation. Other sessions focused on computer-aided drawing (CAD) skills and how to apply additive manufacturing in the engineering design process (specifically 3D printing for prototypes). Prior to the design project investigated in this paper, the first design project focused on a slower progression through the design process (8 weeks), as more time was spent lecturing on the stages of the engineering design process and students were given time to understand these stages prior to working through the stages themselves, as well as attend engineering industry tours during some of the scheduled class times. Specifically, the first project focused on user-centered design and accessibility across a range of everyday tasks, which was used to help students learn the engineering design process using design topics that would be more familiar to them, unlike climate resilience and adaptation, which is far more niche.

The first phase of the project was entitled "Phase 1: Embrace Global Learning in Designing for Climate Resilience and Adaptation." On the first day of Phase 1, the students participated in a lecture where the instructor introduced the concepts of climate resilience and adaptation under an electric power systems lens with an emphasis on global learning. The students were tasked with designing for a location in the United States while applying insights from other countries. Students were reminded that assets could include anything from the physical equipment that plays a role in generation and transmission, and distribution, to infrastructure (e.g., buildings), to digital assets (e.g., data systems and software), and workers (e.g., operators, maintenance technicians), but were prompted to explore these systems at a broader level, as they would later have the opportunity to refine their focus. Specifically, the students were presented with the following design prompts:

1. **Thermal Generation Plants:**

   Thermal generation plants use heat energy to produce steam, which in turn drives a turbine connected to a generator to generate electricity. Plant types consist of fossil fuel plants such as coal and natural gas, as well as non-carbon-emitting nuclear power plants. All types of thermal generating plants are susceptible to various climate and weather hazards. For example, flooding at any thermal generation plant can cause damage to plant hardware, impact operations, and have safety concerns for personnel. How can we, as engineering designers, improve the resiliency of an asset or system in a thermal generation plant under an adaptation lens?

2. **Renewable Energy Facilities:**

   Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Generating facilities include solar and wind, which depend on weather conditions. Other examples include geothermal, hydropower, and bioenergy. All types of renewable generating facilities are susceptible to various climate and weather hazards. For example, flooding at a solar photovoltaic facility may cause electrical failures, corrosion, performance and reliability issues, whereas a drought at a hydropower plant can increase vulnerability to internal erosion during flooding. How can we, as engineering designers, improve the resiliency of an asset or system in a renewable generating facility under an adaptation lens?

3. **Transmission and Distribution:**

Transmission and Distribution (T&D) is the complex system that carries electricity from generators to customers. Once electricity is produced (at a generating station/facility), it is carried to customers (including residential and industrial facilities) via a system of electrical wires known as "the grid." Transmission and Distribution are two distinct stages on the grid, where transmission lines carry high-voltage electricity over long distances from power plants to substations, and distribution lines carry lower-voltage electricity from substations to individual customers. Both Transmission and Distribution are susceptible to various climate and weather hazards. Assets susceptible to hazards include utility poles for Distribution, and metal towers for Transmission, for example. How can we, as engineering designers, improve the resiliency of an asset or system in T&D under an adaptation lens?

With these design prompts in mind, students spent about 15 minutes towards the end of the lecture exploring the Climate READi Vulnerabilities & Adaptation Strategies Inventory [22]. Specifically, the students used the following instructions to guide their exploration:

- Divide the Asset Class categories (excluding Cross-Cutting Topics and End Use Assets) among your team members to explore.
- Depending on the size of your group, one or two team members may need to explore an additional category (there should be 5 categories total to explore). Click the checkbox to the left of each Asset Class to filter it in the inventory.
- Have each team member be responsible for taking notes about their assigned Asset Class. Specifically, each team member should select 4 of the items from the inventory (each item has its own ID number, as defined in the first column on the left). If a team member is assigned two Asset Class categories, then aim for 2 items each.
- For each inventory item, list the Asset Class along with a description from the Vulnerability column and its associated climate hazards from the Climate Hazard column.
- You may do this in a Word document (create a table), Excel document, or on paper. Be prepared to discuss with your team.

Once every team member had the opportunity to provide input on their findings, the team would be able to decide which of the three project objectives they would pursue. An example of what a row item from the VASI tool contains is shown in Figure 1. After the students completed this activity, they took the initial survey.

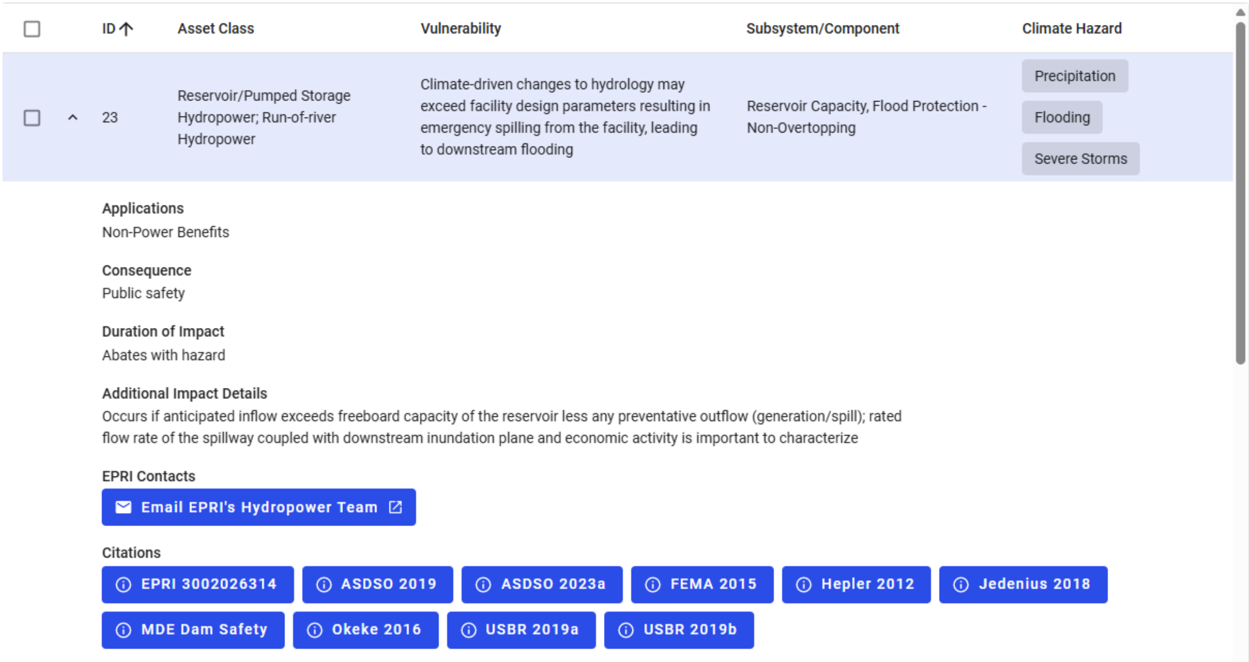

Figure 1. An example of a row item from the Vulnerabilities & Adaptation Strategies Inventory (VASI) displaying information on how impacts from precipitation, flooding, and severe storms can exceed facility design parameters and result in downstream flooding

Continuing on further into Phase 1, each team decided upon which prompt they would tackle for their design challenge, specifically focusing on a specific means of power generation (e.g., nuclear power plants) or within transmission and distribution (e.g., substations). From there, all team members performed individual background research. Specifically, each teammate explored how a particular weather or climate hazard impacts their system, relating their findings back to the other components of risk, which are exposure, vulnerability, and response, as well as noting the location at which the hazards would occur. Students explored these components because they factor into how risks manifest on an electric power system [23], and are thus important to ensuring a resilient design. Furthermore, each teammate explored how a country other than the United States has managed the same weather or climate hazard, aiming for an application of the adaptation outside of electric power systems. Students were encouraged to consider how their selected country's geography, climate, and politics may influence design decisions in their country. Before starting any individual research, the team decided who was to research which hazards.

After the individual research activity, the project progressed to the second phase entitled, “Phase 2: Define a Problem.” Here, each team created a concept map to combine their individual findings and how they relate to each other. An example of a concept map used to demonstrate how to display some of the vulnerabilities associated with nuclear power plants is shown in Figure 2.

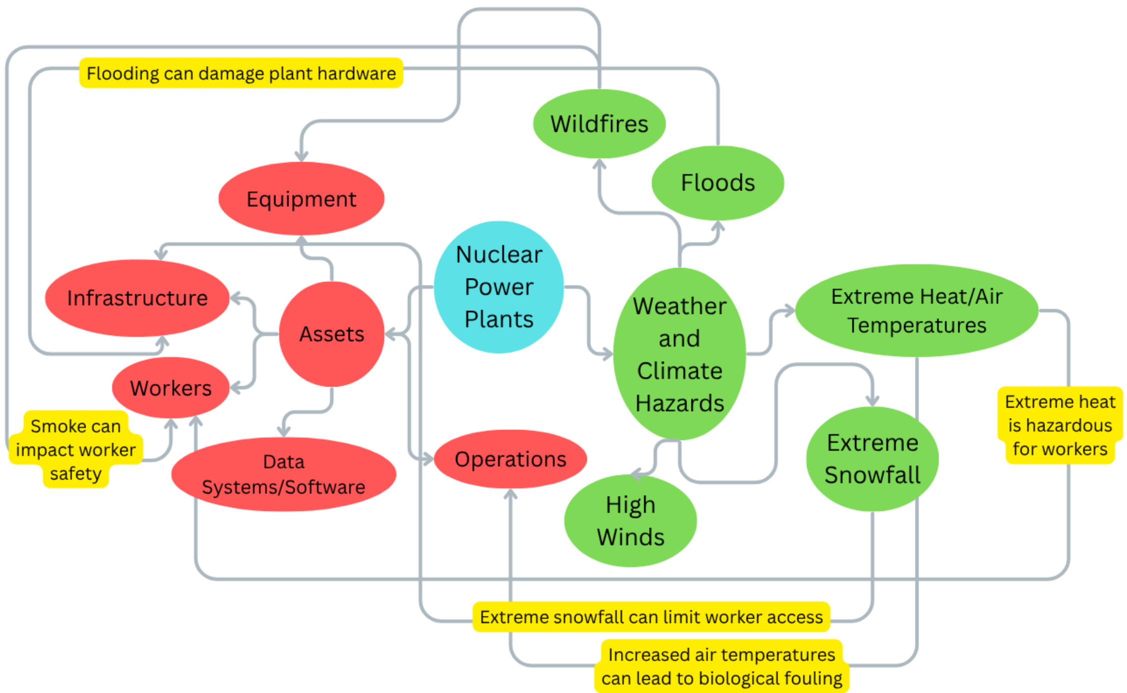

Figure 2. Example of a concept map for a nuclear power plant, showing how various extreme weather events and climate hazards impact it

After the teams created their concept map, they narrowed their focus to a specific issue caused by some hazard and wrote a problem statement to state the design problem that they aimed to address. From there, the teams developed their stakeholder needs and assigned weights to them.

Upon solidifying their problem statements and stakeholder needs, the teams progressed to the third phase entitled, "Phase 3: Ideate Potential Solutions." Prior to any ideation activities, students participated in a virtual reality (VR) session with a curated list of experiences that allowed students to explore various scenarios, such as tours of power plants or experiencing an extreme weather event. Then, the teams started with an individual ideation session, where team members spent about 15 minutes brainstorming their own ideas in silence and then spent another 25 minutes generating ideas as a team and screening until they felt they had about three or four viable options. An example of some of the preliminary sketches is shown in

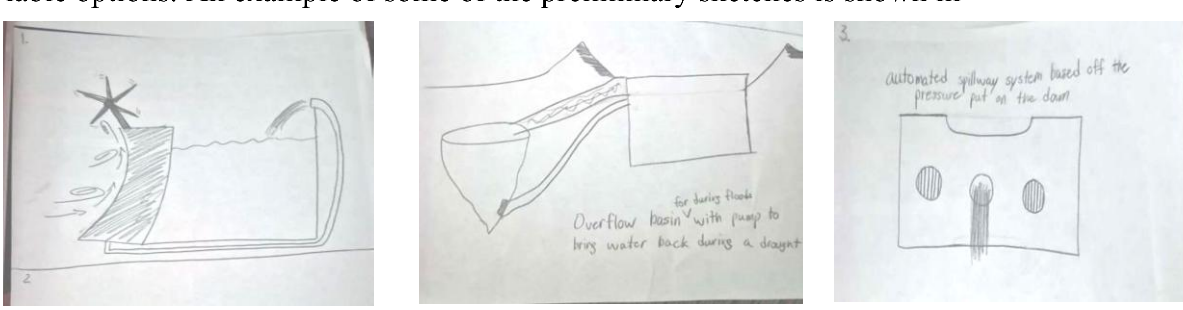

Figure 3.

Figure 3. Various solutions for dam flooding (from left to right: wind turbine, overflow basin, pressurized spillway)

To further explore the design space and promote the development of students' global perspective-taking skills, each team member wrote a short synopsis on a country they would market their design to and what they would need to consider in order for the design to be successful. Specifically, they compared and contrasted how a design for the United States would differ with their target country while considering factors such as culture, the weather and climate, the surrounding environment, and economics. To encourage reflection of the design activities, each student was responsible for connecting at least three of their generated concepts to the prompt.

The teams then returned for another session focused primarily on developing low-fidelity, alpha prototypes of the concepts selected through screening. Alpha prototypes were made of commonly available materials such as cardboard, foam, and other craft supplies. Students were given approximately 25 minutes to develop their alpha prototypes (one prototyped design per student), after which they performed a series of design reviews, where each student met with at least two other students from other teams where they received advice and questions on their concepts. An example of one of these alpha prototypes is shown in Figure 4. Students took notes on the feedback received and wrote a response as to how they planned to incorporate the feedback into the next iteration of the prototype. From there, developed a list of questions and assumptions to investigate to better understand the viability of their design.

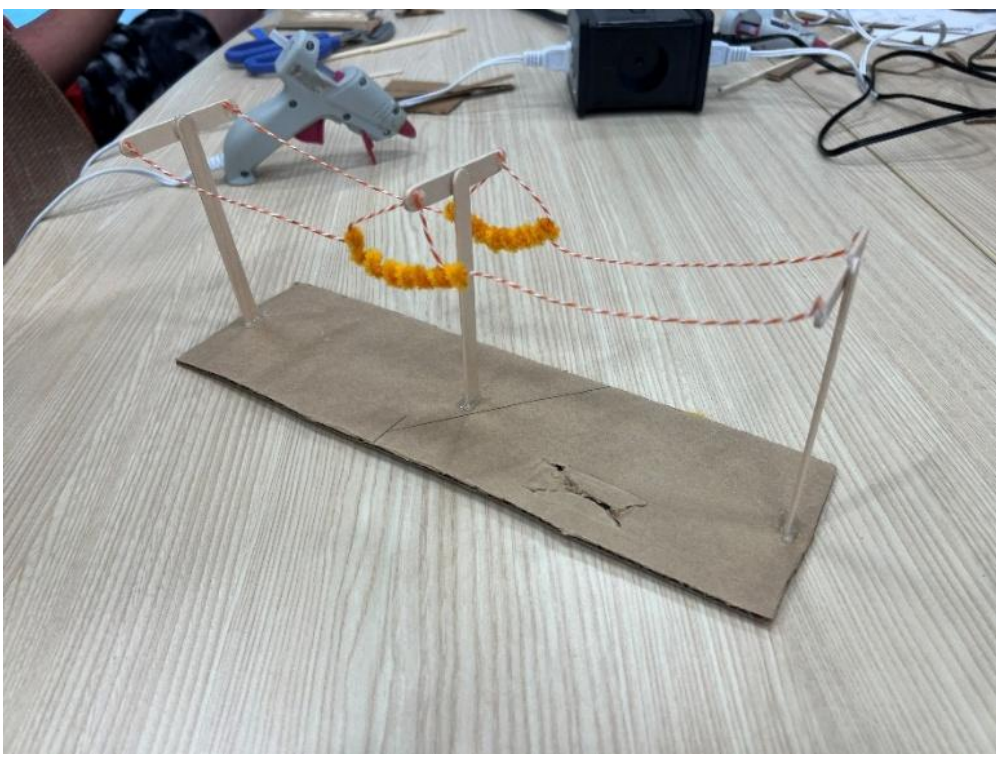

Figure 4. Example of an alpha prototype with power lines that include insulating rods to prevent galloping

Proceeding the design review activity, the project progressed into the fourth phase of the project entitled, "Phase 4: Concept Selection." Here, each team developed their own concept selection matrix to identify which concept(s) best addressed their design challenge and stakeholder needs. After applying the concept selection matrix to guide their decision making, each team developed a system diagram on the concept that they thought would be the most successful, such as the one shown in Figure 5. The system diagram included subsystems that each team deemed important for others to understand their design and served as a means to prepare teams for the beta prototyping stage in the next phase of the project.

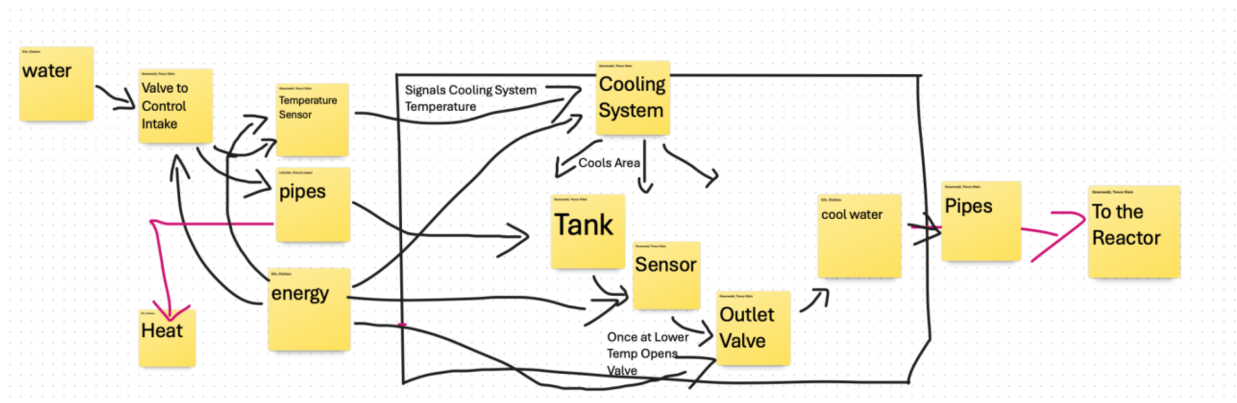

Figure 5. A system diagram for a concept of cooling incoming water for nuclear power plants from external sources (such as lakes or rivers) that are too warm

After completion of the fourth phase, the teams progressed to the fifth and final phase entitled, "Phase 5: Prototyping." This phase began with beta prototyping, where each team pooled their individual members' questions and assumptions from the design reviews in Phase 3 and developed a list of at least five critical questions that they aimed to address with their beta prototype through testing or additional research. Importantly, a beta prototype is of higher fidelity than the alpha prototype, which could be represented as a physical model that demonstrates various processes and features, or a digital model or simulation that addresses the critical questions in a similar manner. Students had some time in class to plan their beta prototypes, but they were primarily responsible for constructing their prototypes outside of class before the due date. An example of one of the beta prototypes is shown in Figure 6**Error! Reference source not found.**.

Figure 6. An example of a beta prototype used that incorporates an adjustable gate system for hydroelectric dam flooding

After interacting with the beta prototype, each team provided a detailed summary of what they learned with respect to their critical questions. From there, each team used the insights gained from their beta prototype to plan out how they would represent their final design. Teams also developed design requirements, identifying what characteristics each team deemed that their solution must meet to be successful. Teams were encouraged to consider aspects such as operating temperatures, weights, and environmental conditions (wind speeds, radiation, water properties, etc.) that could be built into their requirements and were encouraged to use the Vulnerabilities & Adaptation Strategies Inventory [22] a repository for this kind of information. The students addressed the technical design requirements at this stage and not before any of the other prototyping stages because the students were taught that in reality, they would undergo more design iterations for a project of this scale (especially in an industry setting). The overall goal of this project was to introduce them to something more complex with the understanding that technical testing was not expected in a course at this level, but students should be aware of the discrepancies between academic engineering design in a cornerstone course and the engineering design process that is employed in an industry setting.

Upon planning their final designs, each team wrote a design report detailing how each stage of the design process supported their design work. Teams also presented their design process and final designs at a design symposium, which included a presence from local community members affiliated with the energy industry. Final designs were also completed outside of class. One of the final designs is shown in

Figure 7. For this particular design, students were given safety briefings on how to perform electrical work.

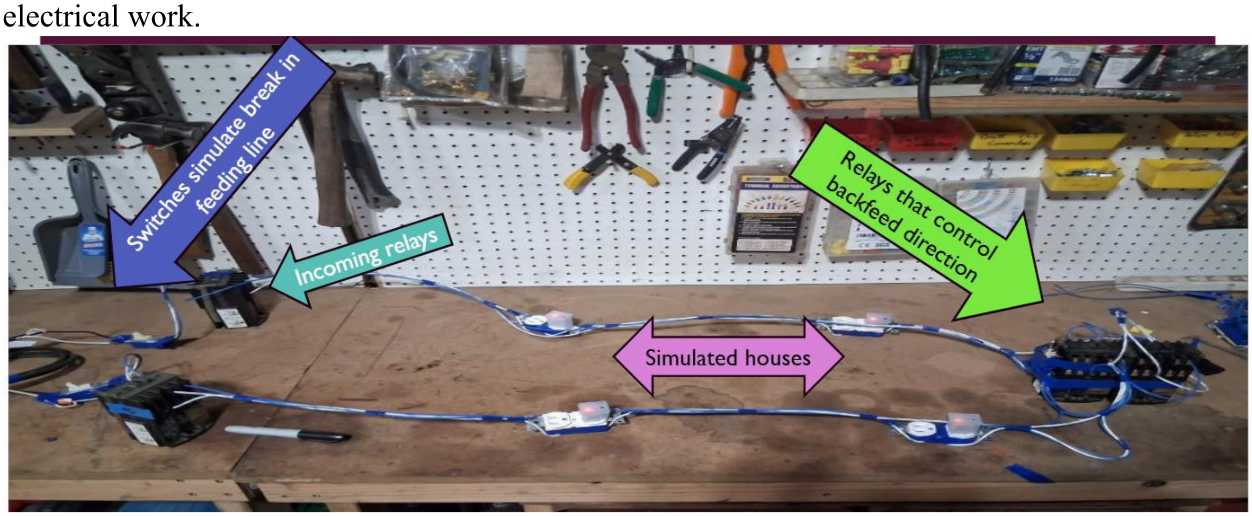

Figure 7. Labeled diagram of the final design for a power grid backfeeding system

After the design symposium, each student completed one final reflective activity focused on developing a response in the form of the cover letter or oral interview response to the question, "Describe a challenge you faced and how you overcame it." Specifically, students were to address this prompt in the context of global perspectives and a skill highlighted in job advertisements relevant to their specific majors that they were tasked with finding. At the end of the project, the students completed the final survey.

Results and Discussion

For the study, 21 students enrolled in the course completed the pre-survey and 24 completed the post-survey. From the post-survey 19 of 24 (79%) participants identified as male; all but six of whom indicated their intention to major in an engineering field (18 out of 24, 75%). The participants were close to evenly split in terms of their status as first-generation college students, with 10 (42%) meeting the definition and 11 (46%) indicating that they did not fit this description. In these results, the calculated average is the mean.

Finding 1: Intrinsic Motivation

The study utilizes two sub-scales of the Intrinsic Motivation Inventory (IMI): interest/enjoyment, pressure/tension, and value/usefulness. For those students whose scores could be matched (n=11), the researchers used paired t-tests to compare the pre- and post-survey results. Overall, the students indicated that they expected to find their engagement in the project interesting, enjoyable, and relevant (see Table 1). The data further affirms that this positive perspective was sustained after the project was completed—nearly all constructs in the scale averaged 4 (agree) or higher in both instances. This finding suggests that projects focused on climate adaptation can motivate students at this level. However, we did not investigate the effects of selection bias, which may have an impact on motivation, as the course itself consists of open-ended design prompts.

Interestingly, the results suggest non-statistically significant changes in perceived stress or anxiety, either before or after the project work, which previous research has suggested can arise in project-based learning, especially for first-year students transitioning from more structured K-12 environments. The means for one of the items related to anxiety ("I do not feel nervous while working on this project") were slightly higher from pre- to post-, but not significantly. Further analysis indicated no significant difference across any of the IMI constructs between first generation and non-first-generation students, though the sample is sufficiently small that this insight should be taken only as suggestive.

Table 1

Student motivation (reported), pre- and post- IMI survey responses:

Survey Item	t-Statistic	df	t-test p-value	Wilcoxon p-value	W	Avg Pre	Avg Post	Pre N	Post N

Survey Item	t-Statistic	df	t-test p-value	Wilcoxon p-value	W	Avg Pre	Avg Post	Pre N	Post N
I find this project very interesting	-1.49	10	0.167	0.346	0	4.18	4.36	11	11
Working on this project is fun	1.15	10	0.277	0.345	8	4.18	3.91	11	11
I enjoy working on this project	0.56	10	0.588	0.665	13	4.18	4.00	11	11
I do not feel nervous while working on this project	1.49	10	0.167	0.188	22	4.09	3.55	11	11
I feel anxious while working on this project (R)	-1.61	10	0.138	0.168	2	2.27	2.73	11	11
I feel pressured while working on this project (R)	-1.94	10	0.082	0.149	0	2.55	2.82	11	11
I believe this project could be of value to me	-1.39	11	0.191	0.371	0	4.33	4.58	12	12
I think doing this project is useful for people in my career	0.00	11	1.000	1.000	10	4.42	4.42	12	12
I would be willing to do a project like this again	-1.30	11	0.220	0.240	7	4.08	4.42	12	12
I think this is an important project	-0.56	11	0.586	0.773	2	4.25	4.33	12	12
I think this project is important to prepare me for the future	0.00	11	1.000	1.000	5	4.42	4.42	12	12
I think this project could help me succeed	-0.69	11	0.504	0.572	5	4.25	4.42	12	12

Survey Item	t-Statistic	df	t-test p-value	Wilcoxon p-value	W	Avg Pre	Avg Post	Pre N	Post N
outside of this course.									

Note: Some survey items have been slightly edited for readability in the table format.

Finding 2: Usability of the VASI tool

Overall, the students expressed consistently high levels of confidence in working with the VASI, with the survey item "I am confident using the VASI tool" averaging 4 (agree) on the pre- and post-survey, respectively. However, their means for multiple usability constructs fell from pre- to post- with one item ("I found the VASI website easy to use") dropping significantly. This result is counterbalanced with the one item that registered a significant increase, "I imagine most people would learn to use VASI quickly" (see Tables 2a). It would appear that the perceived usability of the VASI tool generally did not increase with higher levels of engagement and application.

The usability measure did reflect significant differences related to first-generation status. For first-generation students (n=8), the item "I imagine most people would learn to use VASI quickly" rose significantly (p-value .02 (t-test); .04 (Wilcoxon)) from pre (average of 3.25) to post (average of 4.28). This was also the only survey item in which a statistically significant difference arose between first-generation and non-first-generation participants. In the pre-survey, first-generation students averaged 3.25, while non-first-generation students averaged modestly higher, at 4.20 (p-value .04 t-test; .08 Wilcoxon). Interestingly, the difference between the two demographic groups did not persist, with a slight decline by non-first-generation students balanced by a slight increase in first-generation perceptions. Overall, the averages in the post-survey (average of 4.28 for first-generation, 3.71 for non-first-generation participants) were not statistically different.

Table 2a

Usability of the VASI tool (reported), pre- and post- SUS scale (both first-generation and non-first-generation students):

Survey Item	t-Statistic	df	t-test p-value	Wilcoxon p-value	W	Avg Pre	Avg Post	Pre N	Post N
I would like to use the VASI frequently	0.81	12	0.436	0.608	22	3.38	3.08	13	13
I found the VASI	0.56	12	0.584	0.665	13	3.92	3.77	13	13

Survey Item	t-Statistic	df	t-test p-value	Wilcoxon p-value	W	Avg Pre	Avg Post	Pre N	Post N
website to be simple									
I found the VASI website easy to use	3.41	12	**0.005****	**0.015***	28	4.31	3.69	13	13
I think I can use the VASI without tech support	0.00	12	1.000	1.000	14	3.92	3.92	13	13
I find the various functions on the VASI website to be well-integrated	1.00	12	0.337	0.374	15	4.08	3.85	13	13
I find the various functions on the VASI to be consistent	0.43	12	0.673	0.766	9	3.85	3.77	13	13
I imagine most people would learn to use VASI quickly	-2.50	12	**0.028***	**0.042***	4	3.62	4.15	13	13
I find VASI very intuitive	0.81	12	0.436	0.484	14	3.85	3.69	13	13
I am confident using VASI	0.37	12	0.721	0.777	16	4.08	4.00	13	13
I could use VASI without having to learn anything new	0.69	12	0.502	0.530	22	3.77	3.62	13	13

Note: Some survey items have been slightly edited for readability in the table format.

There were 3 items on the SUS scale in which the perceived usability of the VASI tool (modestly) declined from pre- to post- for non-first-generation students: "I found the VASI easy to use"; "I find the various functions on the VASI website to be well-integrated" and "I could use VASI without having to learn anything new." See Table 2b. This was not the case for first-generation students, suggesting that the students in the course may have reached consensus regarding the tool, with first-generation students registering mild gains from pre- to post-, and non-first-generation students experienced mild declines in perceived usability. It should again be emphasized that these samples are sufficiently small and that any insights should be taken only as suggestive.

Table 2b

Usability of the VASI tool (reported), pre- and post- SUS scale, non-first-generation student respondents:

Survey Item	**t-Statistic**	**df**	**t-test *p*-value**	**Wilcoxon *p*-value**	**W**	**Avg Pre**	**Avg Post**	**Pre N**	**Post N**
I would like to use the VASI frequently	0.00	9.87	1.00	0.863	16.0	3.00	3.00	5	7
I found the VASI website to be simple	1.87	9.65	0.091	0.137	26.5	4.40	3.57	5	7
I found the VASI website easy to use	3.04	10.00	**0.012***	**0.023***	31.0	4.60	3.43	5	7
I think I can use the VASI without tech support	1.82	9.98	0.099	0.134	26.5	4.40	3.71	5	7
I find the various functions on the VASI website to be well-integrated	2.83	6.00	**0.030***	0.060	27.5	4.00	3.43	5	7

Survey Item	t-Statistic	df	t-test *p*-value	Wilcoxon *p*-value	W	Avg Pre	Avg Post	Pre N	Post N
I find the various functions on the VASI to be consistent	0.80	9.64	0.440	0.488	21.5	3.80	3.57	5	7
I imagine most people would learn to use VASI quickly	1.18	9.00	0.268	0.383	22.5	4.20	3.71	5	7
I find VASI very intuitive	2.12	6.00	0.078	0.131	25.0	4.00	3.57	5	7
I am confident using VASI	0.35	6.00	0.736	1.000	17.5	4.00	3.86	5	7
I could use VASI without having to learn anything new	2.50	6.00	**0.047***	0.064	27.5	4.00	3.29	5	7

Conclusion, Limitations, and Future Work

The findings of this study suggest that students remained motivated from the start of the project until the end of the project, making climate resilience and adaptation an appropriate focus area for first-year cornerstone engineering design courses. Furthermore, no significant difference was found between first-generation and non-first-generation students. While this finding is somewhat limited due to the smaller sample size, this is promising for future iterations of this type of curriculum in engineering design courses. Future iterations of this work would benefit from investigating unbiased selection with the project topics and comparing them to other students working with other design challenges outside of climate resilience and adaptation while using the same design framework.

With respect to the VASI tool, students expressed consistently high levels of confidence in working with the tool with little difference between first-generation students and non-first-generation students. This is promising for integrating industry-based tools in first-year cornerstone engineering design projects, showing that students are capable of learning to use and applying these tools when performing background research for their projects.

While this study sheds some light on how climate resilience and adaptation can be applied within a first-year engineering design course, this study is not without limitations. The study relies on student self-report of learning outcomes, an approach that is known to be sensitive to the levels of meta-cognitive awareness, which may be more prevalent in first-year students. Future studies should include more direct measures of learning, such as analyses of student project artifacts. The study is also narrow in scope, focusing on a single semester at a single campus, which limits the generalizability of the results. Future research should seek to replicate the study in more contexts and with different student populations. Furthermore, future iterations of this research would benefit from a longitudinal perspective, focusing on how motivations evolve throughout the various phases of the project.

Finally, it is important to state the potential impact of campus closures across higher education. While the goal is to make comparisons with other cornerstone engineering design courses taught in a similar manner, we acknowledge that students' awareness of a looming campus closure (such as the imminent closure of the campus in this study) could influence responses in terms of motivation and apathy. While this campus in particular has maintained student engagement through various campus activities and field trips to promote positivity, further investigation would be required to see whether engagement in such activities helped to offset any apathy that students would be feeling towards their courses otherwise.

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