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Board 27: Work in Progress: Where We Live: The Process of Building an Experiential-Energy Design Course for Undergraduate Chemical Engineering

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Abstract.

In the engineering curriculum, energy remains a largely abstract concept taught piecemeal throughout various engineering disciplines. Chemical engineering concepts in heat transfer, thermodynamics, and fluid flow can be difficult for students to connect to their everyday experiences of turning the heat on, driving, or using a computer [1]. In a time of an energy transition [2] and promises of achieving net-zero goals, there is a need for students (and faculty) to cultivate an understanding of energy that integrates concepts from fundamental courses with local energy infrastructure. Through local and conceptual understandings of energy, we seek to design a junior-level chemical engineering process safety and design course that helps students develop integrated understandings of heat transfer, thermodynamics, unit operations, electricity generation, and transmission.

In this paper, we, two faculty members in a chemical engineering department, detail our process of designing a new junior-level chemical engineering design course focused on sustainability and inquiry-based learning. We shed light on our own research into local energy infrastructure and provide context-rich instructional decisions for the course design. Building new context-rich courses can be a challenge that is often underestimated and undervalued [3-5]. Ultimately, we designed the course to prepare students for their senior engineering design experience through a locally informed engineering design project based on interviews with sustainability and education stakeholders. Through this work, we developed three objectives of the course: (1) help students bridge their theoretical knowledge of energy with their understanding of the local energy infrastructure, (2) give students the opportunity to apply sustainability concepts within the chemical engineering framework, and (3) analyze the economic, social, and technical impacts of engineering decision-making.

Introduction

As many chemical engineering programs across the U.S. have seen stagnation or decreases in enrollment numbers, there have been efforts to redefine what chemical engineers do. While chemical engineering has strong ties to the oil and gas industry, there are also strong connections to renewable energy, energy storage, and broader sustainability topics. Students across universities have expressed interest and desires to learn about sustainability-focused topics across disciplines. While many faculty in chemical engineering have been working in research and practice of sustainability engineering for years, the undergraduate curriculum has been slower to reflect these changes.

Importantly, sustainability is a cross-cutting space that is defined and operationalized differently across campus. The context of sustainability is important to consider as we develop new curricula for engineering students. While engineering traditionally operates in a value system governed by technical and economic considerations, a sustainability paradigm can help reassess these considerations to value the human and non-human actors. An opportunity within the curriculum to bring together concepts in energy and sustainability is within the capstone design sequence – which asks students to apply the problem-solving process to larger projects. The junior-level design and process safety course is a newly envisioned course for the chemical engineering curriculum at [State University]. This course was created as a way for students to apply their fundamental chemical engineering knowledge in a semi-structured engineering design context before the less-structured capstone project they will encounter in their senior year.

In this paper, we gather education and sustainability stakeholder insights across campus such that our design of a junior-level chemical engineering design course can integrate chemical engineering concepts into the existing sustainability-focused initiatives. Through this work, we interviewed sustainability stakeholders in Facilities and Operations and the Office of Sustainability to learn about existing and future projects around energy and sustainability on campus. Additionally, we interviewed chemical engineering education administrators involved in capstone design and the whole undergraduate curriculum to understand their interests and needs for a junior level design course. This investigative landscape mapping is situated at the [State University], which is an opportune site because of its recent announcement to achieve climate neutrality by 2050 [6]. However, insights can be transferred broadly as many universities and communities have announced their own roadmaps to net zero or climate neutral energy consumption. With many faculty, administrators, facilities engineers, and student activist groups working toward the net zero goals for energy consumption, there is a need to map this local landscape such that chemical engineering students can step into the broader discussion and planning happening on campus.

Background

The engineering curriculum is in constant flux, as these changes are largely a reflection of broader political, economic, and societal priorities in the U.S. For one, the emphasis on engineering design had cycled through the curriculum first as an origin of U.S. engineering in which apprenticeship models and shop work were commonplace through the 1870s. As Bruce

Seely documents, through the 1920s-1950s, there was more curricular attention being paid to the science of engineering. In the postwar era, the emphasis on fundamental math and engineering science took priority in the curriculum. The changes in US engineering followed the engineering programs in France and Germany, which had deep engineering science-focused curricula [7-9]. In the 1990s, the engineering curriculum changed once again. Engineering design was reintroduced to the final year as 'capstone design' and later to the first year as 'cornerstone design' for engineering students. With much attention to these first and final years of engineering programs, there has been less change in the middle years, where much of the engineering science content has remained [10].

Middle Years

While engineering science content remains important, the format in which these concepts are delivered to students has largely remained unchanged since this postwar era when they were introduced. More attention to pedagogical character of the engineering middle years is being paid, but it is far less than that in the first and final years [11]. Nolen, Michor, and Koretsky discuss the fragmentation of content that occurs in the middle years, which corresponds to the difficult students have in transferring content to different contexts. This compartmentalization of courses in the middle years can limit how students approach problems, connect science to practice, and even work together [12]. While there can be an illusion that more contextual work can reduce students' ability to gain conceptual knowledge, there is scholarship that shows these as complementary and reinforcing ideas [11].

Energy Education

For many engineering students, including chemical engineering students, there can be difficulty in connecting different curricular concepts of energy to one another. Topics of energy can span different scales that can be difficult for students to understand in relation to one another—relating Gibbs free energy to electricity to anaerobic digestion. These relations can also be difficult for students to relate to their built environment. Importantly, researchers have argued extensively that students' confusion with energy systems are due to the dualism of lived experiences with energy as electricity, fuel, food etc., and the theoretical material of thermodynamics, steam tables, circuits, dynamics, electromagnetism etc. [1, 13-14].

Focusing on local sustainable energy infrastructure presents an opportunity to bridge students' lived experiences and contextual understanding with the theoretical and abstract curriculum generally used in the middle years of engineering programs [1, 9]. Sustainability is a topic of high interest for many students choosing to go into engineering, however, it largely has become an add-on in engineering curricula [14]. Instead, sustainability can be integrated across topics of energy that is coupled with local infrastructure on campus [15]. All people interact with different forms of energy infrastructure, which can be entry points for students to transfer their theoretical understandings of energy to local contexts.

Methods

Institutional context

We situate this work at a university campus that generates its own electricity, steam, and recycled water [16]. Through existing and proposed local sustainability infrastructure, there is ample opportunity to create a contextual and conceptual framework of local energy relations. Many of the university-wide sustainability initiatives and efforts take the form of large-scale and polished announcements that do not invite student inquiry but try to get ahead of the potential critiques [6], [17-18]. While the tension between students and university employees regarding energy consumption is not new and has increased across campuses in the nation, there are limited opportunities for students to learn hands-on about the sociotechnical decision-making that has gone into the various energy infrastructure projects on campus. Historically, water sources have been a source of stress for the [State University] and communities in the [Town] River watershed [19], culminating in a water reclamation facility that supplies recycled campus water to the on-campus cogeneration power plant [20].

Course context

The junior-level course on process safety and design will be taught for the first time in the Spring of 2026 as a part of a new curricular redesign in an undergraduate chemical engineering program. The course will be a three-credit course, where third-year chemical engineering students will work in teams on a scaffolded design project. This course will be required for all junior-level chemical engineering students—following a cohort model approach across the four years. The major enrollment has varied at the university with parallel national trends but ranges from 40-60 students at a time. Based on the first-year cohort, there will likely be 50 students enrolled in this junior design course in spring 2026. This work in progress study is a way to gather stakeholder insights around what the projects of this course will entail such that they help students meet the learning objectives and connect to local energy projects on campus.

Foundation Questions

To help advance our efforts to connect curricular design in chemical engineering with existing and proposed sustainability initiatives and infrastructures, the authors interviewed stakeholders and experts in sustainability and the chemical engineering curriculum. Our pool of experts included faculty and staff in the undergraduate chemical engineering committee and sustainability and energy efficiency leaders in campus facilities and operations. Through the education stakeholder interviews, we set out to learn about the history of why the junior level design course was proposed. Through the sustainability expert interviews, we set out to learn about existing plans and initiatives at the university around sustainability and energy efficiency.

Ultimately, our purpose for this landscape mapping was to build a course curriculum with a university community that is already very focused on its own energy transition.

Positionality

We approach this project as two junior faculty in the chemical and biomolecular engineering department. Monika is an assistant professor in residence, which is a more teaching focused faculty track and Desen is an assistant professor of engineering education, whose research is focused on engineering education. Monika comes to this project as the future instructor for this course and is interested in connecting engineering concepts to local problems for students. Desen is interested in investigating contextual energy education and ways to connect local infrastructural projects to the engineering curriculum. Her research background includes interdisciplinarity and sociotechnical engineering education.

While the landscape mapping for this new course is an important aspect of building a contextually relevant and integrated experience for junior-level chemical engineering students, this process has been equally enriching for two junior faculty who are newer to the wide-ranging activities happening outside of the engineering college. Through this work, we have sought to seed partnerships and connections with faculty and staff who we may not have encountered previously.

Findings:

Education Stakeholders

To understand the context of this curricular change and implementation of the new course, we set out to gather more information from faculty in the department who were involved in the change. We interviewed two faculty members in undergraduate engineering administration and undergraduate chemical engineering administration. The first is a teaching-focused associate professor and Associate Department Head, who we will refer to as ADH. The second is an associate professor and Associate Dean for Undergraduate Education, who we will refer to as ADUE.

ADUE, who has taught the senior capstone design course since joining the department in 2010, noted numerous factors that prompted the consideration of a junior capstone design course. Particularly, they noted that there has been a historically perceived gap between the senior capstone design course content and the senior capstone design projects. The current model of the senior capstone design course at [State University] pairs student groups with faculty from the department that pitch projects to the students and serve as faculty mentors if their projects are assigned. The course then covers content in design principles, scale up and sizing considerations, economic analysis, process safety, and environmental impact analysis.

Students and faculty mentors express that there is a disconnect in this course layout, noting that the course content requires high levels of effort that take away time that could be given to the design project itself. ADH has also echoed this sentiment, and both agree that the junior design and process safety course is being introduced to address this gap and give students the opportunity to more fully develop their design projects in the senior year. Much of the content in the course also serves to fill specific ABET objectives which are not present in other parts of the curriculum. The addition of the junior level design course, through taking on this content, will allow for the senior level course to be more flexible in its course layout.

ADUE and ADH also highlighted that it would be preferable for students to learn these concepts earlier in the curriculum before reaching the senior year capstone design course. Students would then be more prepared to apply these concepts to their projects from the beginning of the design process rather than retroactively fitting them into their projects. Additionally, ADH mentioned that the course should give students more practice with statistical analysis because the degree requirements currently do not require students to complete a statistics course. Finally, the junior design capstone course will give students the opportunity to carry out and complete a lower stakes design project prior to their main project in the senior year. Having gone through the process once already will hopefully set them up for success in aspects that can be applied across projects such as team and project management and communication.

Sustainability Stakeholders

To position this course within the energy and sustainability work that is already being done at the university, we met with sustainability stakeholders from Facilities Operations and the Office of Sustainability. These offices work together to manage university-wide projects that work to meet university energy and sustainability goals and interface with student groups who are interested in learning more about campus initiatives. We met with a representative from each organization, the first being an Associate Director Energy and Water Compliance from facilities operations, who we'll refer to as ADEW. The second is an Interim Director of the Office of Sustainability, who we'll refer to as IDOS.

In their role, ADEW monitors energy and water compliance across buildings on campus. They spoke of numerous projects taking place on campus which solidified that [State University] is well positioned to offer educational projects centered around energy and sustainability. Several initiatives and facts about [State University] (introducing hydrogen vehicles, fuel cells, solar panels, geothermal power, heat pumps, new metering systems for buildings, and being responsible for our own utilities) underscore the fact that its priorities are in this space and are openly ready for student interaction.

As interim director of the Office of Sustainability, IDOS mentioned three main pillars of the office's work: outreach initiatives, sustainability reporting, and experiential learning. A main aspect of their work includes monitoring data from campus buildings and analyzing the data to be included in sustainability reports. Both IDOS and ADEW noted that, with the implementation of a new metering system on campus buildings, data on water and energy usage can be accessed by students.

Importantly, ADEW and IDOS both recognized that communication with students and student involvement and understanding of their work is critical to their mission as being part of a university. ADEW regularly offers student tours, gives guest lectures, and invites students to ask questions if they are working on larger projects. Similarly, IDOS noted experiential learning and student-based work as one of the main objectives of the Office of Sustainability. IDOS has also stated that they would like to envision campus as a "living laboratory", hoping to give students and student groups the opportunity to implement sustainability focused ideas during their time at [State University]. Their willingness and excitement to engage with students is clear and will hopefully contribute to a collaborative partnership with them as ideas for this course's project aspect are further developed.

Interestingly, ADEW and IDOS talked about the need to communicate to students the structural factors at play when it comes to enacting change at the university. Through working with various student groups, they both find it necessary to explain the systems of power at the university, noting that students regularly express frustrations about the perceived slow pace of change.

In the future, we have plans to work with University Planning, Design, and Construction (UPDC), the office that initiates and plans large-scale building projects. This will hopefully give better insight into projects in the planning and development stage and how university energy usage goals are informing project selection and prioritization.

Key Takeaways

Through our interviews with stakeholders and experts in chemical engineering education and sustainability at [State University], we were able to map out a landscape of existing initiatives and projects that a new junior-level chemical engineering design could fit into. Importantly, these interviews helped contextualize the need for the new course within the chemical engineering curriculum and for more opportunities to connect students to authentic and local infrastructure. In table 1, we detail the points from the education and sustainability stakeholders that have potential overlap. In the third column, we share how we can use both stakeholders' perspectives in the junior course's design.

Table 1. Takeaways from synthesizing education and sustainability stakeholders

Education Stakeholders	**Sustainability Stakeholders**	**Synthesis Takeaway**
Statistical learning is limited for chemical engineering undergraduates.	Facilities Operations collect energy data from most of the buildings and residential halls on campus with plans to install sub meters in each building. These data are provided to the Office of Sustainability which compiles and publishes campus sustainability reports based on the meter data.	Data from the campus meters could be an important way for students to connect their lived experiences in the buildings to their energy use to metered campus energy uses. Their analysis could be compared against the Office of Sustainability reports or used to add further detail to these reports.
Engineering design is too large a topic to teach in the senior year. Students and faculty mentors need more time in the senior year to focus on individual senior design projects. A junior design course could alleviate this burden.	Students are not aware of all the structural issues and real-world aspects of making change or creating new campus energy infrastructure. Students are also not aware of all sustainability and energy-related projects on campus.	We can use the campus and sustainability experts to design a real world, local design project that will introduce junior chemical engineering students to design principles while giving them an understanding of the complexity that goes into the number of sustainability and energy projects currently operating and being proposed for campus.
From the literature, the middle years of the engineering curriculum are largely fragmented and decontextualized. Energy is a topic that can be difficult to connect from conceptual to contextual.	Sustainability experts are interested in building more experiential learning opportunities for students that showcase the number of projects in operation on campus.	

These main takeaways from our community stakeholder research will inform the design of this new course. We offer this paper as a way to provide a different example of curricular design, one that pushes against the siloed nature of universities through local and interconnected examples of campus activity and documents a labor process that often is undervalued in reimagining engineering curricula.

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