Weaving Three Strands Towards Justice-Oriented Sustainability Education

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***Abstract*—The field of Engineering is deeply implicated in processes and systems that are endangering life on earth. The use of fossil fuels is a case in point. The subject of sustainability is usually taught without reference to this implication. I shall present outcomes of a transdisciplinary approach to sustainability education that aims at narrowing this gap. I have combined techniques from Engineering Design, Anthropology, and Peace Studies in a Mechanical Engineering two credit hour technical elective course on Sustainable Energy Systems. The students engage in participant observation, and guided reflection of their chosen artifact throughout the semester. They learn about renewable energy technologies through lectures. They create a proof-of-concept design solution to a community-based project using cooperative learning techniques. Finally, they bring it all together in a class discussion on a case study in lieu of the final exam. The case is of a sustainable district Vauban, Frieburg, Germany. After dissecting its features, they place their artifact in Vauban and examine it from multiple design paradigms and systems of resource consumption. The goal of this student-centered course is to connect the technical concepts of sustainable energy systems to their personal and daily lives.**

Keywords—sustainability; education; student-centered; liberative pedagogies; justice; trans-disciplinary; ecological degradation; climate change; fossil fuels; energy systems

I. INTRODUCTION

The main challenge to action on climate change is posed by major oil & gas companies, which enjoy significant political and economic power [1]. For their operations of extraction of fossil fuels, these companies heavily rely on Engineers and Engineering technologists. Data from Bureau of Labor Statistics indicates continued rise in the jobs in the oil & gas sectors [2]. Most students enter the engineering profession with the incentive of finding high-paying jobs.

The problem of meeting future energy needs is normally framed as a problem of reliance on foreign oil [3]. Consequently, the proposed solution is to access domestic fossil fuels. This is the ideological argument behind the energized research and development in the field of fracking for tertiary oil recovery (in Ohio), and extraction of shale oil (in Utah, Wyoming, Colorado), and tar-sands (in Alberta, Canada).

The oil from tar-sands is purported to add 17% more greenhouse gases to the atmosphere than the traditional oil [4]. With the cost per barrel of oil recovery through fracking fast approaching the cost of traditional oil recovery, the economic case is in favor of fracking [5]. This leads to a very dangerous scenario of accelerated climate change [6].

The rapidly changing climate and ensuing ecological degradation disproportionately impacts people on the margins. These include indigenous peoples, poor people, people in the Global South, and women and children [7]. The climate change then becomes an issue of justice. Understanding the environmental impact of actions of people who own resources is key to reversing these destructive ecological processes.

By demonstrating connection of normative Engineering practice with systems of ecological degradation and social injustice, this work seeks to empower students to seek, demand, and affect change in societal structures to respect life and promote community well-being.

II. A NOTE ON PEDAGOGY

Teaching a course on sustainability poses significant pedagogical challenges that span not only the nature of the subject but the very structures of engineering education.

A. Transdisciplinary Nature of Subject Matter

Understanding the use of fossil fuels to supply for our energy needs, the current infra-structure built on the use of fossil fuels, the ensuing ecological degradation and climate change, and its disproportionate impact on marginalized peoples requires knowledge from fields of Engineering, Chemistry, Ecology, Anthropology, Sociology, and History.

B. Limitations of Traditional Engineering Education

Engineering education on sustainability mostly centers on techniques and limitations of renewable energy resources, and a narrow focus on individual action (for instance, refuse, reuse, recycle) [8]. The question of sustainability is seldom contextualized by examining the implication of engineering practice in enabling unsustainable practices [9]. Consequently, students are not empowered to act in their professional and personal capacities to demand social change.

Engineering education methodology employed traditionally is hierarchical in nature, wherein the professor deposits knowledge to the students who believe their job is to absorb the

information and regurgitate it when needed. This approach entails limited training on sharpening critical thinking skills. The critical thinking introduced in the curriculum operates within the general framework of Engineering profession, which is embedded in the current power structures that are harming life on earth. Justice-oriented sustainability education requires critically analyzing the roots of unsustainability in current practices. This entails understanding the role that the current engineering profession plays in contributing to climate change and offering alternatives to current practices.

C. The Use of Liberative Pedagogies

For a sustained action on an issue of such fundamental nature, it is not sufficient to center the student. The student needs to be empowered to reflect, imagine new solutions, and act to affect change. Friere's praxis provide the perfect mechanism for this process [10].

Considering the limited experiences of most Engineering students outside technical knowledge, they need training for developing reflective tools and analysis. They also need support for taking reflective action.

III. The three strands

The course content is constructed from the disciplines of Engineering and Climate Science. It comprises the physics and engineering of renewable energy generation methods and the impact of the use of fossil fuels on climate. The students apply this knowledge to a "real-world" context, which is provided by a community-based design project. In creating a proof-of-concept stage design, they are guided to critically reflect on current practices pertaining to energy generation and use. This reflection is intended to provide students with a new lens with which to view engineering practice. This critical lens facilitates creation of alternative solutions to our energy needs without compromising life on the planet.

The teaching methods are devised from the techniques of Anthropology and Engineering Design scholarship and are premised on the philosophy of liberative pedagogies. I used the technique of "participant observation" from Anthropology and "community-based design" from alternative engineering design approaches. The students had three strands to follow:

- Developing a critical lens by using participant observation and reflection centered on an artifact.
- Acquiring base knowledge through traditional in-class lectures on climate science, sustainability principles, and renewable energy generation techniques with associated home work.
- Creating an alternative solution in a community-based design project supported by cooperative learning and formative assessment schemes.

A. Developing a critical lens

The ubiquity and dominance of unsustainable energy systems invokes an uncritical acceptance of these systems as the only viable solution. The first task in creating alternatives is to imagine a world different from what we experienced. To facilitate this process, I used a step-by-step approach.

The first step was to introduce the idea that our observations are affected by our positionalities. I employed participant observation technique* to make students aware of their subjectivities when collecting data and making design decisions. The first assignment of the semester was to observe a familiar inanimate object and a familiar process involving human interactions. They were to record both their observations and their emotions during the process. An in-class debrief brought forward the main take-aways: (1) we miss important features of everyday objects unless we carefully observe those; and (2) our emotions affect what we observe and what we miss. This exercise was adopted from Marlys Mayfield and Sara Beckman and is designed for encouraging entrepreneurial thinking [11].

*Participant observation technique emerged from ethnographic research in Anthropology. It aims at accounting for bias in observations. It comprises recording observer's emotions alongside their observations.

The second step was to apply these take-aways to their life contexts. The following assignments were inspired by Chahim and Ullom's seminar course at the University of Washington [12]. The students selected a common, human-made object of their interest, which became an anchor for reflective exercises throughout the semester. This object was termed as 'their artifact.' The students were instructed to acquire the object if feasible or take a clear photograph of it. They reflected on whether their artifact fulfilled the criteria of sustainability that they had defined earlier. They reflected on the mindset and the design paradigm employed by the designer in the light of six design paradigms that they had learnt in Nieusma's paper (Universal design, Participatory design, Ecological design, Feminist design, Socially responsible design, Appropriate design) [13]. They reflected on life-styles supported by their artifact, systems of resource consumption used for the production, transport, and maintenance of their artifact, and ecological degradation caused by the production, use, and disposal of their artifact. They also reflected on whether it was possible for everyone in society to use this artifact sustainably.

These reflection assignments were graded as pass/fail to prevent instructor's bias affecting students' grades. In alignment with liberative pedagogies, students were provided the option to re-write poorly written reflections. Their reflections were mostly thoughtful.

B. Acquiring base knowledge

To be able to imagine alternatives, it is imperative to understand that there is a problem with the current energy systems. The scale of the problem was presented in three stages.

First, the fundamentals of climate science were used to establish the connection between the use of fossil fuels and the rising temperature of the planet [14]. The impact of rising global temperatures on various forms of life on earth was briefly described.

Second, the three pillars of sustainability (environmental, social, and economic) were used to establish the limitations of the economic framework. A guest speaker from Ethical Choices Program [15] presented the damage inflicted by factory farms, which developed to maximize profits, on animals, people, and the environment. To help students appreciate the impact of individual food choices on larger modern agricultural systems, they were assigned a reflection on modern dietary choices and carbon footprint. The following exercise was adapted from Galluzzo, McGivney-Burelle, and Wagstrom [16]. The students examined the data on the carbon emission per calorie for different diet groups and identified that animal-based foods had the largest carbon footprint. They were then able to see the connection between energy-intensive factory farming and higher carbon emissions. They proceeded to project future carbon footprints under the assumptions of constant population growth and same food consumption habits. Their predictions provided quantitative insight into the unsustainability of modern agriculture systems and consequently our current food habits.

To empower students to propose alternative solutions, it is important to provide examples of successful application of principles of sustainability. A guest speaker from Shearer's Snacks Manufacturing facility in Massillon Ohio [17] described how the refuse, reduce, reuse policies at the facility achieved zero landfill goal. The use of rainwater, efficient ovens, and repurposed heat earned the facility environmental responsibility award.

Third, basic knowledge of renewable power generation systems was provided in fourteen 50-minute lectures. We focused on various kinds of solar, wind, and hydro power plants. The students learnt to apply mass, momentum, and energy conservation laws to compute power generated by, and efficiencies of, these systems. They also calculated the carbon footprint of the construction and use of the renewable energy power plants and compared it with that of the traditional fossil-fuel-based power plants [18]. A discussion of the overall environmental impact of these powerplants in comparison with the fossil-fuel-based power plants was also included.

The homework comprised research-based problems. The students worked on these problems in teams. For instance, they calculated the carbon payback period of Three Gorges dam [18]. They were then asked to select a dam of their choice and search for information on whether the carbon payback period was calculated at the time of its construction. In another case, they created a pamphlet for high school students that explained the physics of solar photovoltaics.

C. Creating an Alternative Solution

The practice of freedom in Frierian language pertains to the transformation of reality carried out by collective reflective action (praxis). The design project aimed at providing students with an avenue to affect positive change in their surroundings. The design constraints involved devising creative solutions for fulfilling our energy needs while maintaining life on earth. To connect the design process with their lives and to emphasize choosing "local" as a sustainability principle, projects came from the community.

The students worked on three projects:

1) Off-the-grid electrification of agri/horti-cultural watering system at the University Nature Center

2) Harvesting dissipated energy of swimmers at the University swimming pool during swim practices

3) Educating University students on sustainable practices using an interactive device or a game.

In the past two offerings of this course students have created proof-of-concept stage designs of a bio-digestor for the University cafeteria, solar-thermal heating system for the University swimming pool, electric golf carts for campus navigation, and passive solar heating and cooling systems for a center for water sciences in a local nature preserve.

I made a point of assigning students their first choices to support their enthusiasm in alignment with liberative pedagogies. This meant that 11 students worked on the electrification project (#1), while 4 students worked on the energy harvesting project (#2), and 3 students worked on the educational device project (#3). The 11 students were split into 3 teams. Each team focused on one aspect of the electrification project. The final design was created cooperatively by the three teams.

The design project incorporated higher levels of Blooms Taxonomy. We employed the user-centered design approach, which necessitated close interactions with the clients and users, and included site visits for interviews and observations [19]. The students were expected to work on the design projects outside the class. Guidance was provided in assigned readings uploaded on D2L and weekly meetings with student teams.

IV. SYNTHESIS: CLASS DISCUSSION

To synthesize the three strands, a 3-hour long class discussion created a culminating experience in lieu of the final exam. The class discussion combined features of a "public forum" from Chahim and Ullom's seminar course [12] with a liberal arts-style class discussion. The students were assigned two readings: one on the case study on a sustainably built district Vauban in Freiburg Germany [20], and the other on alternative design scholarship [13] and were provided a set of questions two weeks prior to the class discussion.

Before beginning the class discussion, I reminded students of the features of Frierian pedagogy to validate bringing their experiences to the class discussion. (We had begun the semester with an introduction to Paulo Friere's notion of practice of freedom when discussing the syllabus). Further, I initiated a conversation on what each of them needed for feeling safe to voice their thoughts. This is an evidence-based practice to promote inclusion in the classroom and did encourage the only minority student in the class to confidently voice her ideas.

To facilitate the discussion, I assigned roles to different students. These roles were that of facilitating, time-keeping, taking note of participation, and minutes-taking. I asked for volunteers to fill these roles. The students earned extra points for assuming these roles.

The discussion was anchored by the following questions:

1) Introduce Vauban. Describe its features. What makes it sustainable? Demonstrate with numbers. What makes it a community?

2) Identify stakeholders. These could be residents, governments, policy-makers, politicians, city planners, developers, transportation providers etc. Find a role that resonates with you. You may present the point of view of that stakeholder.

3) Discuss the mindsets and paradigms from Nieusma's article that are applied in the creation of Vauban.

4) Introduce your artifact. Present your artifact to the class. What is it? How was it created? Where did you find it from? Why did you select it? What does it represent to you?

5) Analyze your artifact to uncover the lifestyles (systems of resource consumption) promoted by your artifact. Consider the impact on the environment and ecology of the use of your artefact.

6) Place your artefact in Vauban. Does it fit? Why or why not? Compare and contrast the paradigms and mindsets implied in the creation of Vauban and your artefact.

V. SUDENT RESPONSES AND PEDAGOGICAL INSIGHTS

The students enthusiastically participated in the discussion. Creating a safe space at the beginning of the discussion went a long way towards allowing students to share their honest thoughts. The University being in rural United States, several students found it unimaginable to live without a car. They were also not excited about living in close quarters without much open space. They also found it unimaginable to live in a community without police. They had difficulty understanding that Vauban was a result of collective civic action of people interested in living sustainably. The only minority student in class supported the idea of building such a community in the United States.

The use of artifacts of their choice for reflection purposes helped establish connections between the course content and students' daily experiences. In the words of one student, *"I liked the artifacts and bringing them to class and getting to tie together some of the things we learned in front of everyone based on something that was close to us."*

Students did not exhibit as much enthusiasm for the design projects, however. In alignment with liberative pedagogies, the students were encouraged to propose their own design projects. In the first offering of the course, the students proposed excellent community-based projects. This past year, the students did not come up with any ideas despite several prompts and suggestions. The projects required considerable outside the class work. The course is offered as a technical elective (but this is the only technical elective) for senior year Mechanical Engineering students. The cooperative aspect of the design project also did not work as well. It required considerable coordination outside the class. The students found it difficult to find common times to meet. There was also a question of adjusting to a different way of assessment. Most assignments were graded as Pass/Fail. There was not a system of rewards and punishments in place. Instead I had chosen to rely on the internal commitment and interest of students. This allowed for not assuming pro-active roles when the commitment was lacking.

VI. FUTURE WORK

The current work mainly related to justice to the planet and diversity of life. In the future offering, justice to people will also be incorporated. Drawing on student experience and interests, I shall reduce the scope of the design projects to align those more tightly with the reflection work. I shall also include more class discussions. These will help promote praxis (reflective action) with direct impact on immediate surroundings.

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REFERENCES

[1] L. R. Mayer, "Big Oil, Big Influence." NOW, PBS, August 01, 2008. Retrieved from http://www.pbs.org/now/shows/347/oil-politics.html

[2] Bureau of Labor Statistics. 2017.

[3] J. B. Maverick, "How has fracking helped the U.S. to decrease dependence on foreign oil?" Investopedia. Retrieved from https://www.investopedia.com/ask/answers/012915/how-has-fracking-helped-us-decrease-dependence-foreign-oil.asp

[4] U. R. Fritsche, S. Hunt, K. Fingerman, "Comparison of GHG emissions from unconventional natural gas ("fracking") in key studies." International Institute for Sustainability Analysis and Strategy, Prepared for Eon Mobil Production Germany. Dramstadt, Washington DC, August 2014. Retrieved from http://www.iinas.org/tl_files/iinas/downloads/GEMIS/2014_Fracking_analysis_comparison.pdf

[5] Reuters. Energy. "FACTBOX-Breakeven oil prices for U.S. shale: analyst estimates." October 23, 2014. Retrieved from https://www.reuters.com/article/idUSL3N0SH5N220141023

[6] Intergovernmental Panel on Climate Change. Press release, October 8, 2018.

[7] C. Lee, "Climate justice," The EPA blog. April 24, 2014. Retrieved from https://blog.epa.gov/2014/04/24/climate-justice/

[8] J. Blewitt, & C. Cederic, Eds. The Sustainability Curriculum: The Challenge for Higher Education. Earthscan, 2004.

[9] D. Walls, "The responsibility of the engineer", International Journal of Engineering Social Justice and Peace, under review.

[10] P. Freire, Pedagogy of the Oppressed, New York: The Continuum Publishing Company, 1970.

[11] S. Fixon, "Exercises to practice empathy: The power of observation." In H. M. Neck, P. G. Greene, & C. G. Brush (Eds.), *Teaching entrepreneurship: A practice-based approach*, 2014, Cheltenham, UK: Edward Elgar, 139-145.

[12] D. Chahim, D. Ullom, and S. Bolton, "EGR 202: Engineering for social justice seminar," University of Washington, 2014. Retrieved from https://e4sj.wordpress.com/about/

[13] D. Nieusma, "Alternative design scholarship: working toward appropriate design," Design Issues, vol. 20, Number 3, Summer 2004. Massachusetts Institute of Technology.

[14] R. A. Dunlap, Sustainable Energy, Ch. 4. Cengage Learning, 2015.

[15] K. Allison, [Guest lecture] Ethical Choices Program. Retrieved from https://ethicalchoicesprogram.wordpress.com/program/

[16] B. J. Galluzzo, J. McGivney-Burelle, and R. B. Wagstrom, "What is my carbon footprint?" Mathematics, vol. 109, no. 7, March 2016.

[17] J. Greiner, [Guest lecture] Shearer Snacks Manufacuring Facility. Massillon, OH. Retrieved from https://www.shearers.com/our-commitment-to-our-planet

[18] R. A. Dunlap, Sustainable Energy, Ch. 11, Energy Extra 11.2. Cengage Learning, 2015, pp 305-306.

[19] Engineering Design and Communication. Northwestern University, 2010.

[20] N. Foletta, & S. Field, Case Study: Vauban, Freiburg, Germany. In *Europe's Vibrant New Low Car(bon) Communities* (Simon Field, Institute for Transportation & Development Policy). 2010. Retrieved from https://www.itdp.org/europes-vibrant-new-low-carbon-communities-2/