CHAPTER 37

Role-Playing Case Study on Wind Farm Acoustics: From Technology to Environmental Justice

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Introduction

This chapter addresses integrating sustainability competencies in STEM curriculum design through a summative case study with a role-playing component to help students develop sustainability-related twenty first-century career skills. We discuss students' academic experiences in mainstream STEM fields as opposed to interdisciplinary programs in

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Sustainability Science and examine the extent to which sustainability competencies are addressed in accreditation standards and/or curricular recommendations in STEM disciplines. This is followed by a description of the course's development, the design and implementation of the case study, and student reactions to the course's first offering. We close with a discussion of the potential application of this approach to STEM courses with different content as a model for preparing future generations of scientists and engineers to collaborate effectively with government agencies, environmental justice organizations, and industry to build a sustainable future.

As issues of sustainability and environmental justice have received increasing attention globally and at home, there is "a growing consensus on the need to increase higher education's contributions to developing more effective and equitable responses to a diverse array of sustainability challenges" (Mochizuki and Yarime 2016, 21). Institutions of higher education are responding to this call. According to the Association for the Advancement of Sustainability in Higher Education (AASHE n.d.), there are nearly 700 academic programs in sustainability in the US alone. Students can access everything from certificate programs to doctoral programs in myriad facets of sustainability. Nevertheless, it is unclear whether the graduates of sustainability programs have the specialized expertise necessary to address technological challenges and/or whether scientists and engineers graduating from more mainstream STEM programs achieve the required sustainability competencies. For example, Macias et al. (2022) report that although there is increasing interest on the part of engineers and scientists, their collaborations with environmental justice organizations are not always effective. Through structured interviews, the authors identified these organizations' technology and analysis needs and how they intersect with their strategies for effecting change. One of their key conclusions is that when scientists and engineers move from their more traditional contexts and collaborate with these organizations, they gain sustainability competencies through experience, increasing the social relevance of their technical work. However, these collaborations would likely be more successful if graduates of mainstream STEM programs already possessed a well-developed set of sustainability competencies, along with their technical skills and expertise.

At SUNY New Paltz, US, for example, there is a strong focus on sustainability. The university has a full-time Sustainability Coordinator and an active sustainability committee of faculty, professional staff, and students. The UN Sustainable Development Goals (SDGs) have been adopted as the framework for strategic planning for the campus. Currently, students may choose from among over thirty-eight sustainability-focused or related courses. At this writing, there are 23 students majoring in environmental science and 64 majoring in environmental studies. The campus frequently hosts speakers on climate and sustainability issues, and many students participate in environmental organizations such as the NY Public Interest Research Group. As with the environmental justice organizations discussed by Macias et al. (2022), although many of these students are passionate about environmental causes and climate justice, they lack the technical background to make realistic assessments of environmental problems and potential solutions and often seem unaware of the practical constraints that limit the efficacy of the strategies for which they advocate so fervently.

Meanwhile, the students in mainstream STEM majors who would be best qualified to have meaningful discussions about environmental justice issues appear to be least engaged with these opportunities. Although they may be aware of the issues, their rigorous academic programs leave them little time for extracurricular activities. Their curricula focus primarily on methods that will allow them to arrive at solutions to scientific and technical problems, with little consideration of the environmental or societal impacts of those solutions. They also typically do not observe their faculty instructors and mentors engage with the environmental community and activities on campus. This sets the stage to perpetuate the disconnect between environmental justice organizations and the engineering and scientific community, as Macias et al. (2022) described.

Sustainability Learning Outcomes and STEM Programs

The disconnection described above may be understood by considering the fundamental differences between mainstream STEM disciplines and Sustainability Science, the scientific/technical aspect of Education for Sustainable Development (ESD). Mochizuki and Yarime (2016) describe Sustainability Science as an interdisciplinary field that is "defined by the problems it addresses, rather than by the disciplines it employs" (18). They describe knowledge in relevant disciplines as "multidisciplinarity," the first stage in Higher Education for Sustainable Development (HESD). The next stage is "interdisciplinarity," the integration of knowledge from these domains to understand the interactions between humans and the environment to solve problems. The third and final stage is "trans-disciplinarity," wherein those solving the problems collaborate with and learn from members of the sector of society being affected by the problems and solutions (18–20). Typically, all three stages would be integrated within a single course, or the first two would be included, with a separate course or academic experience that introduces the third. Moving through these stages allows students to acquire a number of competencies in the area of sustainability.

Although different courses in sustainability will, of necessity, have diverse student learning outcomes (SLOs), specific competencies can be identified as common threads. When students explore a problem from multiple perspectives (transdisciplinary stage), they develop what Wiek et al. (2016) refer to as the "systems thinking" competency. The "strategic thinking" competency develops in the second stage as they integrate knowledge from these disciplines and begin formulating solutions. Because these solutions must take into account ethics, equity, and social justice, students necessarily begin to develop the "values-thinking" competency. As students move into the third stage, trans-disciplinarity, wherein they must collaborate and interact with affected members of society, they hone the "values-thinking" competency in addition to developing interpersonal skills. Ideally, as a summation of these experiences, they will develop the "futures-thinking" competency, giving them the tools to be change agents in their professional careers (242). However, mainstream major programs in STEM areas do not necessarily offer students the learning experiences that will help them develop these sustainability competencies.

Most departments in mainstream STEM disciplines offer general education courses that address topical issues to promote scientific literacy and help non-science majors understand the relevance of STEM to their lives and society. The programs offered for majors are far less likely to include courses that address societal issues, let alone develop sustainability competencies. Students must first acquire the specific knowledge and skills in their discipline. In some technologically intensive programs, students barely have time to complete their requirements and may only have exposure to topical issues if they participate in an undergraduate research program or external internship. Others may provide more such opportunities within the curriculum, especially if there is a professional association that dictates accreditation requirements or offers voluntary curriculum guidelines. For example, a recent draft of the American Chemical Society's guidelines for undergraduate programs includes learning outcomes in "green chemistry and sustainability" development of "expertise at the interface of chemistry to help …solve problems that span scientific disciplines" (American Chemical Society 2023) and outcomes related to "systems thinking." The current guidelines of the Accreditation Board of Engineering Technology, ABET, have two out of the seven learning outcomes that relate to sustainability competencies:

> Outcome 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
>
> Outcome 4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

The first outcome requires students to integrate the "values-thinking" competency by analyzing engineering problems that have societal and/or environmental impacts (systems thinking) and proposing solutions (strategic thinking) that address the stated extrinsic factors. The second learning outcome places additional emphasis on values thinking and seems to lead toward the futures thinking competency. Any engineering program that is ABET-accredited will be able to pinpoint components of one or more courses that are intended to address these outcomes, but without going through the three stages of HESD described above, the degree to which sustainability competencies will be achieved is unclear. It can be challenging for educators to find opportunities for their students to develop sustainability competencies due to the demands of teaching the extensive technical material associated with the curriculum. For engineering students to meet these learning outcomes, their curricula must require them to grapple with technological challenges in sustainability, integrate multidisciplinary knowledge, reflect on human and societal values as they weigh possible strategies, and connect more holistically with the end-users and others affected by their decisions. Students typically have little or no experience grappling with these issues in their everyday engineering training. A well-designed case study involving multidisciplinary learning and role-playing can provide these opportunities.

Role-Play Case Study

Case studies involving sustainability and environmental issues provide a unique opportunity for STEM students to tackle technical and ethical aspects simultaneously and understand the importance of connecting them in their future professional responsibilities (Bartz and Deaton 1996; McConville et al. 2017). Including a role-playing component in a case study presentation provides additional opportunities for students to develop awareness of environmental justice issues (Martin et al. 2019; Walther et al. 2012).

A wind energy workforce development and engineering education grant allowed our campus to create a series of short courses related to wind energy, including one on wind farm acoustics. Wind farm noise can negatively impact residents living nearby and frequently is a barrier to community acceptance. Therefore, instruction in wind farm acoustics should consider human and environmental impacts, providing a rich opportunity for STEM students to develop sustainability competencies and meet ABET Student Outcomes 2 and 4 by considering real-world case studies of wind farm noise and community impacts. In this specific example, the interdisciplinary course includes the following subject areas: wind turbine design (engineering), physical acoustics (physics), sound perception (psychoacoustics), and environmental impacts (ecology).

Students develop the "systems thinking" competency by integrating the information from multiple disciplines. By exploring their perceptions of sounds, including wind farm noise, and "hearing" the voices of stakeholders through case study materials and sources, students develop the "values-thinking" competency. As they weigh possible solutions and consider how decisions they make can affect human and non-human species, they are developing the "strategic thinking" competency. Finally, they move into the "transdisciplinary" phase as they present, discuss, and debate their solutions in the role-play activity, enhancing their interpersonal skills and working toward the "futures-thinking" competency (Fig. 37.1).

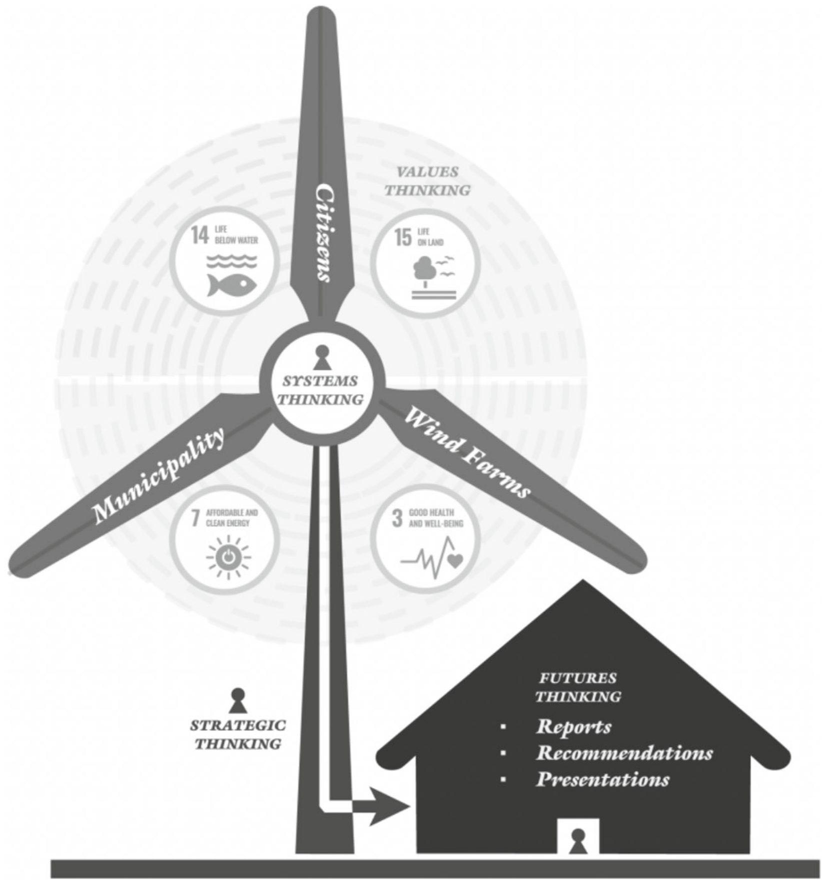

Fig. 37.1 This graphic illustrates the relationship between the UN Sustainable Development Goals and the Higher Education Sustainability competencies & ABET SLOs in the context of a role-playing case study. The UN SDGs that pertain to wind energy are the background of the turbine and frame the values-thinking of the students. The turbine blades represent the roles the students assumed in the case study as they use systems thinking to analyze the noise problem caused by the wind turbines from the perspective of their role. The turbine tower represents the integration of the proposed solutions using strategic thinking. As the students interact to work out solutions, they apply values thinking and hone their interpersonal skills. The result, illustrated through the house being powered by the wind turbine, represents the use of futures thinking in engineering problem-solving.

Wind Farm Acoustics Course Description

The goal of this course is to encourage science and engineering students to engage in analyzing systems; devise strategies to reduce human impacts of wind farm noise; and promote acceptance of this form of green energy within the context of global, societal and economic factors. The course is open to any student who has completed a course in introductory physics, including students with a major or minor in environmental science.

The UN SDGs are the preferred framework for this course because they are widely accepted and potentially useful to our students in their future careers. Specifically, the applicable global goals are:

SDG 3 Health and Well-Being—Impacts of wind farm noise on humans SDG 7 Affordable and Clean Energy—Wind Farm engineering design
SDG 14 Life Below Water—Impact of wind farms on marine species
SDG 15 Life on Land—Impact of wind farms on terrestrial species

Course Structure

The five-week course was designed as a "flipped classroom" hybrid, with 75-minute weekly in-person classes reserved for discussion, demonstrations, lab activities, and homework support. The first four weeks consisted of online readings, video lectures, quizzes, assignments and in-class activities. These components of the course have multiple goals (SLOs):

- Give students the technical background they would need to interpret the case materials and reports
- Introduce students to the perceptual aspects of wind farm noise through listening activities to help them understand the impacts of wind farm noise on nearby residents
- Introduce principles of noise control engineering so they can propose realistic technical solutions

The students prepared and presented their case study project during the fifth week.

Development of Role-Playing Based Case Study

The wind farm selected for the first iteration of this course was Nā Pua Makani Wind Farm in Kahuku, Honolulu, Hawaii. The siting, construction, and operation of this wind farm have been very controversial due to the proximity of the turbines to community areas such as schools, and the adverse effects experienced by local residents. Along with environmental and noise assessment reports, documents describing the residents' concerns are readily accessible online. Links to the primary source resources provided to students can be found on the Earthrise Commons (earthrisecommons.org). These include governance regulations, government and corporate information sites, required technical reports, data sites, scientific journal articles, news reports, documents, ethnographic research, public comments, environmental justice advocacy groups, direct contact with community stakeholders.

Identification of Information Sources

To develop a role-playing current events-based case study, you must know the scope and depth of material available to the students as they prepare. The material can be gathered ahead of time and provided directly to the students, or the instructor can furnish tools to guide the students in their fact-finding journey. Regardless of how the material is gathered, students will also need guidance on how to use the information they have at their disposal.

Development of the Student Roles

Recent research into engineering education has demonstrated that students learn to address the social factors related to sustainability and ethical issues effectively when engaged in relevant role-playing (McConville et al. 2017; Martin et al. 2019). Role-playing can be incorporated into a case study by forming teams of students and assigning each team member to represent a specific stakeholder involved in the controversy. In the case of the Nā Pua Makani Wind Farm, groups of three students were formed, and each of the three students was instructed to select one of the three roles provided. These roles were developed based on our perception of different groups who may employ an acoustics engineer to represent their concerns:

Role 1: Acoustics engineer for wind farm. You are an acoustical engineer for the company that owns and/or operates the wind farm. You have been involved in the acoustical aspects of this wind farm's development, construction, and operation. You feel strongly that wind energy is a critical component of your state's commitment to increasing its usage of renewable energy and strive to develop efficient and inexpensive noise control measures that will allow the wind farm to continue operating as efficiently as possible without causing harm to the residents.

Role 2: Acoustics engineer for the local municipality. You are an acoustics consultant hired by the local municipality to help them address residents' concerns. Your goal is to evaluate the residents' concerns based on the local regulatory statutes as well as information that has been provided to you by the wind farm developers in the Noise and Sound Level Assessment Report(s), and use this information to help the city council respond to the concerns that have been raised in a way that continues to address the state's required clean energy initiatives, continues to promote the economic well-being of the city, does not put undue cost on the municipality, and can withstand legal challenges by the wind farm.

Role 3: Acoustics engineer for the residents. You are an acoustics consultant hired by the residents to help address their concerns. Your goal is to evaluate the residents' concerns based on the local regulatory statutes as well as information that has been provided to you by the wind farm developers in the Noise and Sound Level Assessment Report(s), and use this information to help the residents have their concerns met in a way that promotes their well-being, is not interpreted as being anti-clean energy, and does not put undue cost on the residents (through energy price hikes or increased local taxes).

Instructions for the Case Study Development and Presentation

On the last day of the course, each group of three students collaboratively presents an acoustical background for their wind farm and then engages in a mock town hall-style meeting with the local concerned residents. During the town hall-style meeting, students conduct an informal discussion to develop a plan for addressing each of the invested parties' concerns and the instructor provides questions when necessary to keep the conversation focused. After completing the discussion, students share their impressions of the experience.

Description of Case Study Requirements

The students were instructed as to what type of information to use in developing their collaborative portion of the presentation as well as their individual, stakeholder specific solutions. Elements include: acoustical background; location; acoustical assessment; regulations; residents' concerns; noise control measures by role; regulations; administrative controls; wind turbine remediation; additional compensation (see Earthrise Commons; earthrisecommons.org).

Outcomes of First Offering

Student Case Study Presentation

Student Reaction

Due to the small class size, the college's student evaluation of instruction was not available. About four months after the course ended, the students were asked to send us comments about what they learned from the course and any perspectives they had gained. One student wrote that the final presentation "helped me a lot to learn about the problems that today's society faces and how it can be improved." Another wrote that, "It's not so simple to just implement clean energy and there's positives and negatives to something that just seems like it should be an obvious solution. The town meeting simulation …. gave me a new perspective on how lawmakers operate and how it might not be so simple to do the right thing…" This student concluded, "Renewable energy actually isn't the perfect solution I had originally thought it was….I still believe it's the correct solution, but it comes with some downsides that professionals will have to continue to iron out and have to explain transparently to the public before simply making the switch to green energy in every circumstance…. I genuinely had a black-and-white perspective before this course." (*All comments used with permission*).

Next Steps/Further Development

The next iteration of this course will be in an asynchronous online modality. Although most of the materials are already available in the college's learning management system, this transition will require revision of some course components. Students will conduct some lab activities individually rather than in a group setting. Other demonstrations have been filmed, and students will be given the data to analyze rather than making the measurements themselves. The case study project will require students to collaborate online to give their final presentations and conduct their discussions, which will then be submitted as a video.

Conclusion

Overall, this course provides the technical background that the students need to analyze a topical Engineering case study and grapple with human well-being and environmental, societal, and ethical issues. Student reactions from this first offering suggest that this scaffolded case study project can help learners meet the two ABET student outcomes. Because the course is open to students in other majors who have completed a physics course, there is the potential to have a mix of Engineering and Environmental Science participants, which would bring multiple perspectives to the discussion to benefit both student groups.

An additional benefit is that students were exposed to noise control engineering. Engineering students typically receive no training in acoustics or noise control engineering. It is not required for licensure as a professional engineer and is not included explicitly in ABET student outcomes (Wang et al. 2021).

Because this is an elective course, it does not obviate the need for ABET outcomes 2 and 4 to be met through other required courses, but it provides an additional opportunity to reinforce these outcomes in a more focused manner. The approach described here provides a general framework and could be adapted to other engineering topics related to a wide range of current societal and/or environmental problems.

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