Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
ASEE
Paper ID #45979

Engagement in Practice: Lessons Learned from Using COAST to Teach Environmental Modeling

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Engagement in Practice: Lessons Learned from Using COAST to Teach Environmental Modeling

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Abstract

Previously, we reported details of pedagogy as well as student feedback on a course to teach systems modeling to environmental engineers. As part of this existing modeling course, a module was developed leveraging a research project that employed community-engaged design to create the world's first parametric insurance product protecting the livelihoods and food security of artisanal, small-, and medium-scale fishers in the Caribbean. In this article, we report details of the content of the module as well as assessments of student learning and feedback from students with regard to the value of the module to introduce concepts of community-engaged design. In particular, these results are discussed in the broader context of the United Nations Sustainable Development Goals, specifically the five Ps – partnerships, peace, people, prosperity, and planet.

Introduction

The criteria for accrediting engineering programs approved by the engineering accreditation commission of ABET include Criterion 3, "Student outcomes" [1]. Student outcome number one includes, "an ability to identify formulate and solve complex engineering problems by applying principles of engineering, science and mathematics." Student outcome number two includes, "an ability to apply engineering design to produce solutions that meets specified, needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors" As previously reported, we developed and delivered a semester long course in environmental modeling to upper level undergraduates, as well as graduate students enrolled in the programs of civil architectural and environmental engineering at the Missouri University of Science and Technology [2]. As part of this course, students applied mathematics to solve problems, which considered global, cultural, social, environmental, and economic factors. This type of systems approach is typical of environmental engineering [3]. A unique aspect of this course was engagement with communities. In particular, the course focused on problems that had relevance to communities that had suffered historical discrimination. This includes communities of the Caribbean, where there is a history of chattel slavery and oppression through colonization. A previously described research project was used to create a module for the course [4][5][6].

As originally published in 2009 by the American Academy of Environmental Engineers and Scientists, the body of knowledge of environmental engineering includes 18 outcomes [7]. These outcomes are arranged in three areas, namely: foundational outcomes; enabling knowledge and skills outcomes; and professional outcomes. Within the enabling knowledge and skills outcomes is Outcome 8, "Sustainability". According to the body of knowledge, "the environmental engineer has a critical role in the emerging sub discipline of sustainable engineering … environmental engineers must integrate sustainability principles into the engineering systems that they themselves design, build, or operate to protect, environmental human health and well-being," [7]. As part of the body of knowledge document, the level of achievement is specified for different students. A course, which provide advanced education for upper division undergraduate students as well as early career graduate students, should include the ability to analyze the sustainability of an engineered system using tools such as lifecycle assessment. As previously reported, lifecycle assessment was integrated as part of the semester long course in modeling [8]. In addition, the environmental engineering body of knowledge includes Outcome 14, "Effective Communication". Effective communication includes interactions with the public as well as the technical community. The level of achievement specified for upper division undergraduate students as well as early career graduate students specifies, "plan, composed, and integrate verbal, written, virtual, and graphical communication of a concept or project to technical and non-technical audiences." As part of the module, students create a written document, which is provided as part of their grade assessment.

According to ABET, the program criteria for environmental engineering and similarly named engineering programs specify requirements for the curriculum and the faculty [1]. Curriculum requirement "d" specifies the design of environmental engineering systems that, "includes considerations of risk, uncertainty, sustainability, lifecycle principles, and environmental impacts." The module incorporated into the semester long, modeling course specifically examines issues of risk of severe storms, including hurricanes, in the Caribbean.

The Caribbean is a sub region of the Americas bordered by North America to the north, Central America to the west, and South America to the south. The Caribbean includes thousands of islands and small land bodies. Governance in the Caribbean includes a number of independent nations as well as overseas territories. The primary international governing body is the Caribbean Community or CARICOM. CARICOM includes 15 member states and five associate members.

The Caribbean is prone to natural disasters, including hurricanes, as well as regular earthquake activity. In 2007, Caribbean governments formed the Caribbean Catastrophe Risk Insurance Facility or CCRIF. The parametric insurance policies offered by CCRIF provide member governments rapid access to a cash payout within 14 days following a trigger event. In 2014, the United States Department of State announced a partnership with CCRIF to create a new insurance policy. COAST, or the Caribbean Ocean and Aquaculture Sustainability faciliTy, is designed to support food security in the fishery sector, as well as to improve the sustainable management of catch fisheries [9][10][11]. In 2018, the first COAST policies were placed with the governments of Grenada and Saint Lucia. These policies included three levels of coverage. The first level of coverage was for recurring rain and wind events, which prevent fishers from working. The second level of coverage included larger storms, which create damage to the fishing fleet as well as shore-based infrastructure. The third level of coverage was for catastrophic events, such as a direct hit by a major hurricane.

Details of the creation of the COAST insurance policy – including community-engaged design – are shared with students as part of the course module [12][13][14][15][16]. Students are then invited to offer suggestions for improvements to the insurance scheme. Community engagement is accomplished by requiring the students to understand the local conditions of fishers in the Caribbean. For this course, community engagement is accomplished through a review of the literature (i.e., [9][12]) and through the sharing of first-hand experience by the instructor. The students prepare a written report as an assessment of their grade. Evaluations by students are accomplished during the end of semester course evaluation's which are online, anonymous surveys completed by students.

Methods

Institutional context. Located in Rolla, Missouri, the Missouri University of Science and Technology was founded in 1870 as the Missouri School of Mines. In 2023, a total of more than 7,000 students (approximately 1,500 graduate and 5,500 undergraduate) are enrolled in approximately 100 degree programs. Currently characterized as a Carnegie R2, a doctoral university with high research activity, S&T is home to three colleges. Within the College of Engineering and Computing, the Department of Civil, Architectural, and Environmental Engineering (or CArE) is one of the largest and most research productive programs on campus.

Course description. Environmental systems modeling, CArE 5605, is offered every autumn semester as a 3 hour lecture. The course description states, "Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing." There is no textbook; rather readings are provided for each module. Each course module includes learning, objectives, background material, as well as student assessment. The course includes six modules. These are:

1. course introduction;
2. Introduction to systems science;
3. Langmuir isotherm and activated carbon for taste and odor removal;
4. Streeter-Phelps and transferrable discharge permits for river water quality;
5. Gaussian plumes and policy evaluation for air shed protection;
6. Application of systems science to sustainable development;

Students may also complete an optional term length project. The term project is focused on COAST, or the Caribbean Ocean and Aquaculture Sustainability faciliTy.

Details of COAST module. The objective of this term project is to demonstrate how to use systems thinking to inform sustainable development using access to parametric insurance to promote food security and sustainable management of marine capture fisheries throughout the Caribbean in an era of intensifying hurricanes due to a changing climate [16].

By the end of this term project, students should:

1. describe the application of system thinking to international development
2. define the paradigm of disaster and development
3. appreciate the application of systems thinking to the development of holistic interventions to promote international development in the face of extreme weather

Working independently, students construct a model linking the behaviors of fishers in the Caribbean to pre-storm and post-storm behaviors that reduce vulnerability to storms and improve management of fisheries to protect livelihoods and food security by adapting to intensifying hurricanes attributed to a changing climate.

The PowerPoint slides used to introduce this module are included in Appendix A.

Results

The course, CArE 5605, environmental systems modeling, is offered every autumn semester at S&T. The COAST module is included as an optional term length project. The PowerPoint slides used to provide the lecture to introduce the course module are included in appendix a. In brief, students are introduced to the concept of diplomacy lab. Created by the US Department of state, diplomacy lab is an opportunity for students at US universities to work with faculty on projects identified by the US Department of state. As COAST was developed as a product of a collaboration of the US Department of state and CARICOM, the module is introduced to students as part of Diplomacy Lab [17]. The problem statement for the optional term project includes: construct a model, linking the behaviors of fishers in the Caribbean to pre-storm and post storm behaviors that reduce vulnerability to storms and improve management of fisheries to protect livelihoods and food security leveraging parametric insurance. The final product is a written report submitted by the student. The report includes 10 sections, which are:

1. Providing a narrative of the overall problem and identifying important states and relationships
2. Including the ranges and typical values of states
3. Including a pictorial representation of the system, with explicit notation for states and relationships
4. Listing assumptions
5. Using the assumptions to reduce the model to a solvable sub model
6. Creating a mathematical representation of the sub model
7. Implementing a solution to the mathematical representation
8. Interpreting the results of the solution
9. Conducting a sensitivity analysis of the solution
10. Describing the lessons learned in the overall exercise

As part of the introductory lecture, students are introduced to some of the challenges in the Caribbean. These include a reliance on small scale fishing faced with a pattern of bad weather [16]. The practice of small scale fishing often includes a cultural artifact of a history of colonial rule and neocolonial influence. For example, while many fisher's in the Caribbean fish for subsistence, others fish for the purpose of engaging with tourism, which can include bringing tourist on fishing excursions as well as selling the best catch to hotels entertaining tourist. As the continued emissions of carbon dioxide result, in a change in climate, the severity of periods of bad weather are more intense, more frequent, and last longer. This creates a risk of life and equipment for the fishers. The continuing influence of tourism may contribute to exacerbating this risk as fishers will pursue fishing activities, even in dangerous sea conditions. Some of the technical solutions to this problem include enhanced early warning systems that provide fishers with information about when sea conditions are dangerous. A financial solution to this problem includes the availability of parametric insurance. COAST is an example of parametric insurance.

Initially conceived by and funded by the United States Department of State, COAST aims to solve a number of the Sustainable Development Goals. In particular, COAST is designed to support food security, which is imperative to achieve SDG two zero hunger. As an insurance instrument, COAST also helps prevent the disruption of livelihoods, which is imperative to achieve SDG one no poverty. As part of the module students are asked to explore how COAST can support the achievement of SDG 14 life below water. Specifically students explore the concept of build back better, which is part of the cycle of disaster and development, which is intrinsic to the pattern of hurricanes experience in the Caribbean. Recognizing that severe storms, including hurricanes, are unavoidable, the COAST insurance policy can help fishers prepare before a storm, as well as recover after a storm. Some examples of behaviors that fishers may adopt before a storm includes changing the type of gear used for fishing (i.e., the use of modified lobster pots designed to prevent ghost fishing in the event of their loss during a storm event) [9][12]. An example of behaviors that fishers may adopt after a storm, includes changing the type of vessel used for fishing (i.e., from a two stroke outboard motor to an inboard motor vessel, which produces less nearshore pollution) [9][12].

Collectively, the background and content of this module are explained in the broader context of the five Ps – partnerships, peace, people, prosperity, and planet. People are supported through access to food and a reduction in loss of life due to dangerous fishing. The planet is supported through a change in fishing behaviors to reduce activities which damage catch fisheries. Prosperity is supported through a financial instrument of parametric insurance. As part of a diplomacy lab project, the students understand how partnerships are encouraged between developed and developing nations. An additional aspect of this work is an introduction to the concept of peace. As described by Drexel University's program of peace engineering, the goal of peace is to prevent and reduce violent conflict through education and research, which integrates technologies and policies of peace building. Drug trafficking from South America to the United States through the Caribbean is an attractive alternative form of income for fishers. While a focus on law enforcement by the United States would be one mechanism to prevent the flow of narcotics, a second approach includes supporting the livelihoods of Fischer's throughout the Caribbean. In this way, support for sustainable development simultaneously protects the national security interest of the United States.

As part of end of semester, student evaluations of the course, examples of optional feedback related to this module included (lightly edited to enhance readability):

- "I really liked the modules on the problems in Guatemala and in the Caribbean. I never understood that sustainable development is something that helps the interest of the United States. I always felt that international aid was a giveaway. I now realize there are benefits through partnerships between the United States and other countries."
- "One of the best parts of working on the term project was the opportunity to share with other students the ideas I was developing throughout the semester. With each module during the semester, we learned new skills, and I was able to apply these to the problem of the Caribbean."
- "I think you should swap the modules on Guatemala in the Caribbean. While stunting in Guatemala is a good problem to study, I think the problem with fishers in the Caribbean

was more interesting. I would rather see all students work on the problem in the Caribbean, rather than just an optional exercise."

- "The international projects were too difficult, because they required us to understand cultural situations outside of our experience. Without seeing the situation firsthand and speaking to the fishers directly, it's difficult to understand how to create a new product."
- "I preferred the project that focused on taste and odor control in Chicago and Lake Michigan over the project in the Caribbean. It shouldn't be our problem to solve their issue. Everyone knows there's bad weather."
- "It's great that you worked at the US Department of state, but I don't think it's appropriate to use coarse time to solve a problem for the US government."

The feedback received from students on the module can be grouped into three types. First, some students recognized the purpose of the exercise and thoroughly enjoyed participating. This is the type of feedback that was sought. Second some students noted that it is difficult to work on social issues outside of context. Future effort should explore how to connect students work to direct engagement with people from the region. This could include online connections through zoom, or perhaps, inviting individuals from the Caribbean region, living here in the United States to join in discussions in the classroom. The third type of feedback is disappointing, but fair. As part of higher education student should feel comfortable to express their preferences on course content. Future work should explore ways to improve students understanding of an appreciation for issues of international sustainable development. Connecting Americans, especially in the Midwest, with issues of international development, remains a challenge.

Discussion

A module on the use of parametric insurance to protect the livelihoods and food security of fishers in the Caribbean was incorporated as part of a semester long course on environmental modeling. This course is offered as an elective to upper division, undergraduate students as well as graduate students. Details of the institutional context as well as details of the pedagogy and content of the course module are provided.

An analysis of the free responses from students collected at the end of the semester indicated three types of responses. Frist, some students indicated enjoyment and learning with the module, while other students expressed a concern about a lack of appropriate, cultural context. And finally a minority of students expressed frustration with undertaking an exercise that included an international component. It is interesting to note that none of the comments were opposed to the idea of community engagement. But rather some students expressed a concern of a lack of understanding the appropriate context and other students expressed frustration with the communities that were being studied.

The COAST fisheries insurance model provides an opportunity to discuss the five Ps of the United Nations Sustainable Development Goals, specifically – partnerships, peace, people, prosperity, and planet. The results from the module and the course demonstrate an increase in student knowledge of principles of community-engaged design as well as an increase in student awareness of the benefits of the foundation of Agenda 2030, which is described by the United

Nations as, "an aspirational plan to build a more equal, more just, more sustainable, and more prosperous world for future generations."

The results of this study are consistent with prior reporting that environmental engineering is a caring profession [18], and it highlights the value of working together as part of interprofessional teams [19][20] to address the challenges of planetary health [21][22]. Besides this module on the Caribbean, the overall course includes exposing students to concepts of sustainable development to support food security in the Caribbean [23] as well as access to employment in the information economy in East Africa [24].

Limitations and Future Work

An important limitation of this work was the lack of direct interaction between the students in the course and the community of Caribbean fisherfolk who participate in the COAST insurance policy. While the instructor has first-hand knowledge and interaction with these community members, the students were not directly engaged with the community. Future work could consider the use of COIL, or the Collaborative Online International Learning Exchange, to make meaningful connections between people, cultures, and ideas – in this case, between the Caribbean fisherfolks community and the community of students in this course.

A second limitation of this work was the use of a single model of sustainability, namely, the P5 model of the UN SDGs. Future work could consider the use of ENVISION, which is a comprehensive tool developed by the Institute for Sustainable Infrastructure (ISI).

A third limitation of this work is the reliance on qualitative feedback from students. Future work should use the existing qualitative feedback to develop and validate quantitative measures, which could be used in evaluating the success of COAST.

Finally, an additional limitation of this work is the use of a module within a single course at a single institution. Future work should explore if the lessons learned in this study are of general utility when teaching community-engaged practice regardless of the student type or the details of the course content.

Conclusion

Three lessons learned from teaching this module include:

1. provide an opportunity for students to become acquainted with the content over an extended period of time (i.e., this module is completed as part of a semester-long, optional term project, which allows all students exposure to the material and an opportunity for asking questions and digesting "new" content over the entire semester);
2. provide sufficient detail on the foundational content (i.e., this module included a full length lecture on the UN SDGs as well as specific lectures on people, planet, and prosperity); and
3. provide repeated opportunities for students to learn from peers (i.e., a think-pair-share approach is used as part of the pedagogy of the course, and students noted that it was

easier to “digest and accept” the content when discussed with peers rather than as delivered in lecture from a faculty member).

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Appendix A.

1

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course: CArE 5605
Title: Term Project

2

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

What is Diplomacy Lab?

- See: https://www.youtube.com/watch?v=JBydZVg4s8k
- See: https://diplomacylab.org

3

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

What is Diplomacy Lab? Part Deux

- U.S. Department of State Partners with America's Universities
- Helping Solve the World's Biggest Challenges with Diplomacy Lab Program
- Diplomacy Lab is designed to address two priorities:
  - first, the determination to engage the American people in the work of diplomacy.
  - And second, the imperative to broaden the State Department's research base in response to a proliferation of complex global challenges.
- The initiative enables the State Department to "course-source" research and innovation related to foreign policy by harnessing the efforts of students and faculty experts at universities across the country.
- Students participating in Diplomacy Lab explore real-world challenges identified by the Department and work under the guidance of faculty members who are authorities in their fields.
- This initiative allows students to contribute directly to the policymaking process while helping the State Department tap into an underutilized reservoir of intellectual capital.
- Teams that develop exceptional results and ideas are recognized for their work and may be invited to brief senior State Department officials on their findings.

4

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

The optional term project

- Construct a model linking the behaviors of fishers in the Caribbean to pre-storm and post-storm behaviors that reduce vulnerability to storms and improve management of fisheries to protect livelihoods and food security leveraging parametric insurance.

5

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

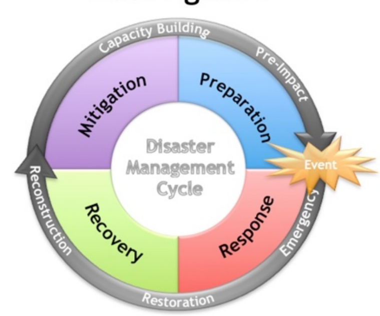
Let's check out an example…

- Ses:
  - https://www.youtube.com/watch?v=4iYzU2Poh1Q
  - https://www.youtube.com/watch?v=MVvQfpI3_iA

6

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

From Development to Disaster and Back Again…



7

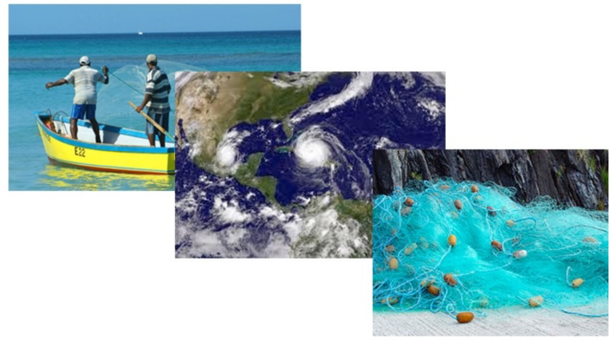
Parametric Insurance to Manage and Transfer Risk

HOW DOES PARAMETRIC INSURANCE WORK?

8

Missouri University of Science and Technology

Weather, livelihoods, food security



9

Missouri University of Science and Technology

Weather risk for Caribbean fisherfolk (1/2)

- The challenges of climate change and variability faced by fishermen and women in four Caribbean countries are to be addressed through early warning and emergency response tools being developed under the Caribbean Regional Track of the Pilot Programme for Climate Resilience (PPCR).
- The information, communication and technology (ICT) solution, which is being developed by the ICT4Fisheries Consortium in collaboration with the Caribbean Regional Fisheries Mechanism (CRFM), will work to reduce risks to fishers' lives and livelihoods posed by climate change and climate variability. The ICT4Fisheries Consortium is a multidisciplinary team comprising members from The University of the West Indies (UWI), the University of Cape Town and the Caribbean Network of Fisherfolk Organizations.
- Possible impacts of long term climate change trends and short term extreme weather events on Caribbean fisheries include damage to fishing and aquaculture community infrastructure, including roads, harbours, farms and houses caused by sea level rise and stronger storms, as well as unsafe fishing conditions and loss of life at sea as a result of strong storms and hurricanes, according to a 2015 study published by the Food and Agricultural Organisation (FAO).

10

Missouri University of Science and Technology

Weather risk for Caribbean fisherfolk (2/2)

- Other hazards influenced by climate, such as sargassum seaweed, are also of deep concern to fishers.
- The ICT-based early warning system is expected to reduce fisher folks' vulnerability to the impacts of climate change. Using an application for mobile phones, fishers will be able to receive early warnings of risky weather and sea conditions.
- The mobile application will also be used to encourage fishers to share their local knowledge to support and improve climate-smart fisheries planning, management and decision-making. The system will be integrated within existing national disaster risk management and emergency response frameworks, and its main focus will be on communications.
- From: http://www.caribbeanclimate.bz/caribbean-early-warning-system-to-help-caribbean-fishermen-deal-with-climatefishermen-who-depend-on-fishing-for-a-living-need-an-early-warning-system-change/

11

Missouri University of Science and Technology

The Problem

Artisanal fisheries

Bad weather

12

Missouri University of Science and Technology

The Source

CO2 emission

Colonial rule

13

The Solution

Capacity, Technology, Finance

14

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

What exactly does this 'optional assignment' include?

1. Providing a narrative of the overall problem and identifying important states and relationships
2. Including the ranges and typical values of states
3. Including a pictorial representation of the system with explicit notation for states and relationships
4. Listing assumptions
5. Using the assumptions to reduce the model to a solvable sub-model
6. Creating a mathematical representation of the sub-model
7. Implementing a solution to the mathematical representation
8. Interpreting the results of the solution
9. Conducting a sensitivity analysis of the solution
10. Describing the lesson/s learned in the overall exercise