Advances in Engineering Education

2022: VOLUME 10 ISSUE 1

Household Energy in Guatemala: An Interdisciplinary Course Series Integrating Learning, Research, and Praxis for Impact

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ABSTRACT

Many of today's engineering students are seeking international, intercultural, and interdisciplinary educational opportunities that involve acquiring real-world project experiences while working toward making a difference in communities. Even as university teaching and learning is tied to terms and learning modules and therefore has certain constraints, educational programming should be balanced with lasting contributions to long-term goals of the partners and communities with which they interact. To achieve these goals, Oregon State University's humanitarian engineering program offered a two-part faculty-led study abroad course focusing on technologies and policies to meet household energy needs in rural Guatemala. During a 1-credit background course, a triad of stakeholders worked together to identify and formulate research questions for student-led team projects. These projects supported current and long-term objectives of the partnering researchers, U.S.- and Guatemala-based NGOs, local entrepreneurs, and communities in Guatemala. The research questions were then investigated during a 3-credit summer field course that followed. For the NGO and OSU researchers, these goals included gathering systematic data regarding user perceptions and adoption of the technologies for donor reporting requirements, measuring performance, facilitating co-development of user-driven designs, evaluating new usability protocols, and developing new sensor-based monitoring tools to quantify impact of cooking technologies. For the local manufacturing partner EcoComal, the primary goals involved improving workflow processes, optimizing stove performance, and contributing to manufacturing cookstoves. Communities were also supported through income-generating opportunities and subsidized cookstove distribution. Results showed that through this model both praxis and knowledge were advanced, partner projects and missions were supported, new technologies were commercialized, and data collected contributed to support donor financing and publications. Lessons learned point to the value of long-term partnerships outside of the course itself, the need for attention to fair trade learning and communication, and preparing for flexibility in the field when executing the projects.

Key words: study abroad; humanitarian engineering; co-design

INTRODUCTION

Many of today's post-secondary students are seeking opportunities to help solve challenges that face low resource or other marginalized populations, generating increased demand for curricular and co-curricular experiences that focus on these social goals in higher education (Seemiller and Grace, 2016; Mehta, 2015; Creed, Suuberg, and Crawford, 2002). This desire to improve quality of life and more effectively meet basic needs is particularly true of students historically underrepresented in STEM fields, especially women, and therefore, is of interest to programs seeking to attract and retain a more diverse student body (Dzombak, Mouakkad, and Mehta, 2016; Jesiek, Shen and Haller, 2012; NSB, 2016; Busch-Vishniac and Jarosz, 2004; Nilsson, 2015). Efforts to meet these demands is evidenced by the growing membership in the National Academy of Engineering's (NAE's) Global Grand Challenge Scholars program that now has over eighty participating national and international universities (NAE, n.d. a). There are also ubiquitous opportunities for academic and co-curricular projects aimed at reducing global inequities, often in sectors such as food, water, energy, shelter, and medicine that include innovation, social entrepreneurship and service learning (Dzombak, Mouakkad, and Mehta, 2016; Passino, 2009; Amadei and Sandekian, 2010; Kickul et al., 2018). Projects frequently focus on addressing issues identified by the United Nations' Sustainable Development Goals and the NAE's Global Grand Challenges, both of which emphasize direct collaboration with communities, thereby encouraging student travel abroad to allow for participatory design and development (Skokan, Simoes, and Crocker, 2006; NAE, n.d. b; UN, n.d.). The impact of these programs is evaluated not only on the technical aspects of the project, but on the environmental, economic, and social benefits as well (Amadei and Wallace, 2009; Stevenson et al., 2018; MacCarty and Bryden, 2016).

While hands-on service learning opportunities are becoming more common due to demonstrated benefits to student learning and the development of both "hard" and "soft" engineering skills, their real-world sustainability and impact is often questioned (Anderson et al., 2006; Arthur and Achenbach, 2002; Smith et al., 2016; Ba-Aoum, 2016; Bielefeldt, Paterson, and Swan, 2009; Ritter et al., 2018). Some argue that short-term student-centered experiences may not meaningfully contribute in practice to goals for sustainable development or provide measurable benefits to the communities with whom they engage (Amadei and Wallace, 2009; Brikke and Davis, 1995;

Rittner, 2019). Student travel incurs significant expense and environmental footprint. The presence of students and faculty can put a strain on communities and projects can promise outcomes that may not materialize or sustain in the long term (Amadei, Sandekian, and Thomas, 2019; Kellogg, 2004). Some organizations are attempting to combat this shortcoming, such as Engineers Without Borders (EWB) who require that teams secure 5-year minimum commitments for community partnerships. All EWB projects are initiated within the community rather than at the university chapter (EWB, n.d). The Forum for Education Abroad, a professional organization focused on standards of good practice, provides guidelines for international community engagement, service-learning, and volunteer experiences (Forum for Education Abroad, 2018). Best practices include engaging with established organizations that are committed to including diverse voices and empowering community members to be involved in program development, implementation and evaluation of programming, where there is 'reciprocity of value' in terms of the learning goals and attention to mitigating any harmful effects or unintended consequences.

As evidenced throughout this special issue, the question is how can universities approach international, project-based, service-learning in ways that achieve a better balance between student learning and real-world impact. Some of these discussions suggest that programs should increase focus on serving the host communities in a way that is community-driven, promotes a "fair trade" of the benefits from any program, is interdisciplinary in skillset and scope, and prioritizes long-term impacts over short-term outputs (Reynolds et al., n.d.; Hartman, 2015; Hartman et al., 2019). This paper explores strategies to apply these best practices in the formulation of a short-term faculty-led study abroad course in the humanitarian engineering program at Oregon State University.

BACKGROUND

The Humanitarian Engineering, Science and Technology (HEST) program at Oregon State University (OSU), founded in 2015, offers students the opportunity to use "engineering in context" by considering the environmental, economic, and social impacts in addition to the technical applications. Humanitarian engineering endeavors to provide technical solutions to address basic human needs, enhance life quality, and advance community resilience locally and globally (humanitarian.engineering.oregonstate.edu). HEST was borne out of the need for curricula that not only engages but enables students to "make a difference" and be of service, and simultaneously attract and retain students who are underrepresented in engineering. Founding and contributing faculty from disciplines such as engineering, anthropology, and public health frequently focus their research and teaching on addressing unmet needs in various types of marginalized populations.

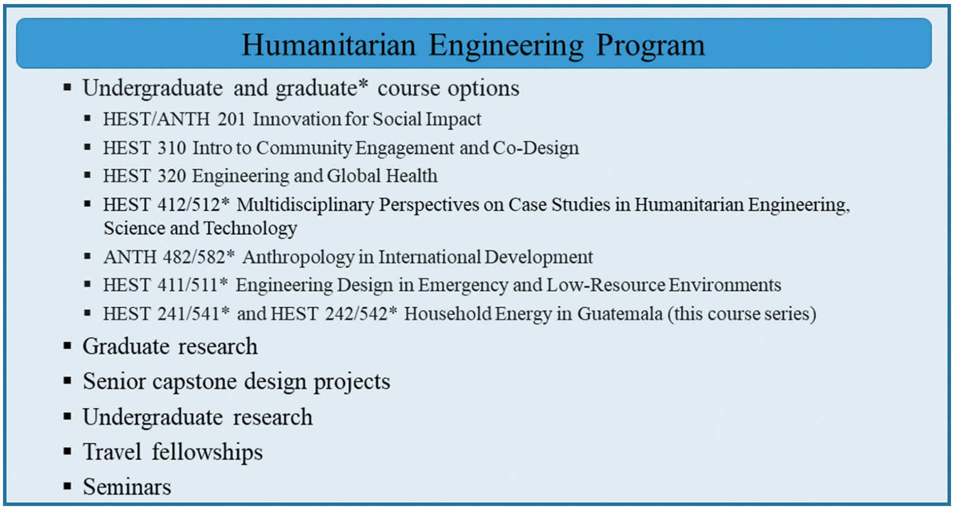

Figure 1. The humanitarian engineering program at Oregon State University.

The HEST program based in the College of Engineering offers an undergraduate minor featuring interdisciplinary courses that align with OSU's general education requirements so as not to increase time or credits needed to graduate (Figure 1). Many of these courses are project-based and experiential. In addition, there are senior capstone design projects, seminars with visiting scholars or graduate researchers, and undergraduate research opportunities focused on the program's mission. There are also a number of engineering and non-engineering affiliated faculty advising graduate research in this field. For both undergraduate and graduate students, travel fellowships are available to support in-field research projects. The curricular activities focus on creating real-world impact while emphasizing the importance of understanding and communicating with the target users by applying principles of co-design and holistic impact assessment.

Of these opportunities within the humanitarian engineering program, the focus of this article is on the development and assessment of a short-term faculty-led study abroad program involving a term-length pre-departure/background course and a two-week field course entitled "Household Energy in Guatemala," created in 2016. This article will introduce the course pedagogy and mechanics, including the genesis, philosophy, partnerships, learning and impact objectives, content, and assessment. It will then discuss the results from two program offerings (in 2016 and 2018) including student enrollment and outcomes from both the learning and impact perspectives. Finally, the article will explore lessons learned that are applicable to the development of similar courses at peer institutions as well as to future plans for the course and OSU's humanitarian engineering program as a whole.

COURSE PEDAGOGY AND MECHANICS

Course Genesis

Early on in the development of the humanitarian engineering program, OSU engineering faculty recognized the need for an immersive, international experience for students that includes in-depth learning on a specific and pervasive global development issue. Assistant Professor of Mechanical Engineering, Dr. Nordica MacCarty (author) who has worked in the clean cookstove sector as an international consultant for over a decade, offered to develop a two-part course series with a focus on household energy poverty. As defined by the International Energy Agency, household energy poverty is a lack of access to modern energy services such as electricity and clean cooking fuels, and typically involves reliance on solid biomass fuels burned in open fires. Today over one-third of the world's population (2.7 billion people) relies on these campfires for more than 95% of their daily energy needs (Legros et al., 2009; Johnson and Bryden, 2012). This traditional practice results in 4 million premature deaths each year due to household air pollution and significant contributions to anthropogenic climate change (Lim et al., 2013, Masera et al., 2015). The course series being discussed was initially developed in 2016 in collaboration with co-instructor Dr. Elizabeth Schroeder, Associate Professor in the School of Public Policy with expertise in development economics, and later in 2018 and 2020 with Julie Walkin, Faculty-led Program Manager in the Office of Global Opportunities.

The goals and mindset for this course include:

1. Take a broad and inclusive approach, welcoming students from a variety of majors and disciplines, class standings, and experience levels so that the focus is broader than simply the technical aspects of technology implementation but also considers social, policy, and economic implications.
2. Provide program activities that are community/partner-driven and support university/partner longer-term goals for research and implementation so that students are contributing to larger, existing, and enduring efforts.
3. Require that travel occurs only after students gain foundational knowledge about the relevant issues and context through a preparatory course so that their participation in the experience and contributions to the projects are better supported.

To meet these goals, the course was developed as a two-part series to include preparation during a 1-credit background course (HEST 241/541), followed by immersion in rural Guatemalan communities during the 3-credit, 12-day study abroad course (HEST 242/542). To date, the course series has been offered three times, once in 2016 and once in 2018, with a 2020 offering planned with 20 students registered until COVID-19 led to cancellation of all programming involving travel. The background course is offered during spring term, while the field course occurs at either the beginning or end of the following summer term, allowing for minimal disruption to students' summer jobs or internships.

During the course series, students gain an understanding of household energy needs in developing countries as well as of the social, environmental, technical, and economic issues surrounding technologies and policies to help meet these needs. Qualitative and quantitative data gathering including experiments, observations, and surveys are used to evaluate the outcomes and impacts produced by a variety of household energy technologies, particularly biomass cookstoves, in student-driven team projects aligned with their own interests and needs of the partners. This provides students the chance to practice their research, engineering, and cross-cultural communication skills under a variety of circumstances.

The course is conducted in partnership with three long-standing organizations with strong ties to the target communities:

- **StoveTeam International (StoveTeam)**, an Oregon-based non-profit that helps local entrepreneurs establish self-sustaining factories in Latin America to produce safe, affordable, fuel-efficient cookstoves to replace dangerous open cooking fires (stoveteam.org).
- **EcoComal**, StoveTeam's partner factory near Antigua Guatemala, that manufactures and disseminates several models of improved cookstoves (ecocomal.wordpress.com).
- **Link4**, a Guatemala-based social enterprise that fosters local innovation and sustainable development through design, capacity building, and social impact experiences (link4.gt).

Philosophy

The course was conceptualized with the goal that students contribute to the partners' active projects, research, and implementation, rather than simply conduct a choreographed educational exercise. With growing concerns for climate change and economic disparities, incurring the costs and carbon emissions of sending 10–20 people to Guatemala are more readily justified if there are lasting outcomes. Therefore, the ongoing projects and goals for each partner organization are discussed as the course is being developed each year. These items are then integrated into the curriculum, and presented as potential research projects for the student teams.

A second key goal of the course is to help students develop their broader competencies as articulated in the NAE Grand Challenge Scholars Program (NAE, n.d.b). These include:

1. **Talent Competency**: *"Mentored research/creative experience on a Grand Challenge-like topic."* This competency is developed through formal and informal mentoring relationships between students and the instructors and partners, both during the pre-departure course and while in the field.
2. **Multidisciplinary Competency**: *"Understanding the multidisciplinarity of engineering systems solutions developed through personal engagement*." Poverty reduction is an inherently complex

issue that calls for an interdisciplinary approach and perspective is essential to creating sustainable solutions. The differing skill sets of mechanical engineering versus public policy students enables completion of a broader set of deliverables and a more holistic discussion, while also informing the different disciplines of the tools available in the others' discipline, thus enabling them to see the value of each other's contributions.

3. **Viable Business/Entrepreneurship Competency***: "Understanding, preferably developed through experience, of the necessity of a viable business model for solution implementation*." Through direct engagement with local designers, entrepreneurs, and implementers, the reality of implementing engineering-based solutions is better understood.
4. **Multicultural Competency**: *"Understanding different cultures, preferably through multicultural experiences, to ensure cultural acceptance of proposed engineering solutions*." Participation in homestays, use of the traditional and proposed technologies for daily tasks, and discussions of challenges and solutions with users during co-design activities creates a more meaningful cultural understanding.
5. **Social Consciousness Competency***: "Understanding that the engineering solutions should primarily serve people and society reflecting social consciousness*." Firsthand experiences of daily challenges and living conditions in different socioeconomic and cultural venues reveal the true context of technology applications.

In addition to these specific competencies, the program partners seek to help students develop broader T-shaped skills of self-awareness and expression (Wu, Zou, and Kong, 2012; Oksam, 2008), skills that are not typically included in traditional engineering curriculum. Therefore, meaningful reflection is a large part of the course, taking the form of group sharing and personal photo/journaling assignments.

Finally, encouraging participation from students and faculty with varying levels of experience and from different disciplines is helpful to provide opportunities for both mentoring and learning. As a result, a mindset that all participants are both teachers and learners is instilled throughout the course. In this way, students learn not only from faculty and co-instructors, but also from each other, from the partners who also provide content, and from the community members. At the same time, faculty and partners learn from the disciplines and experiences within the diverse student cohort. In addition, a mindset of being open to the experiences in the field and considering the positive aspects of life in rural villages is encouraged to alleviate or avoid the "white savior" complex (Cole, 2012; Bandyopadhyay and Patil, 2017).

Partnerships

The course is designed to provide a synergistic collaboration between three major stakeholders: the students, the community and NGO partners, and the MacCarty Research Lab within OSU's

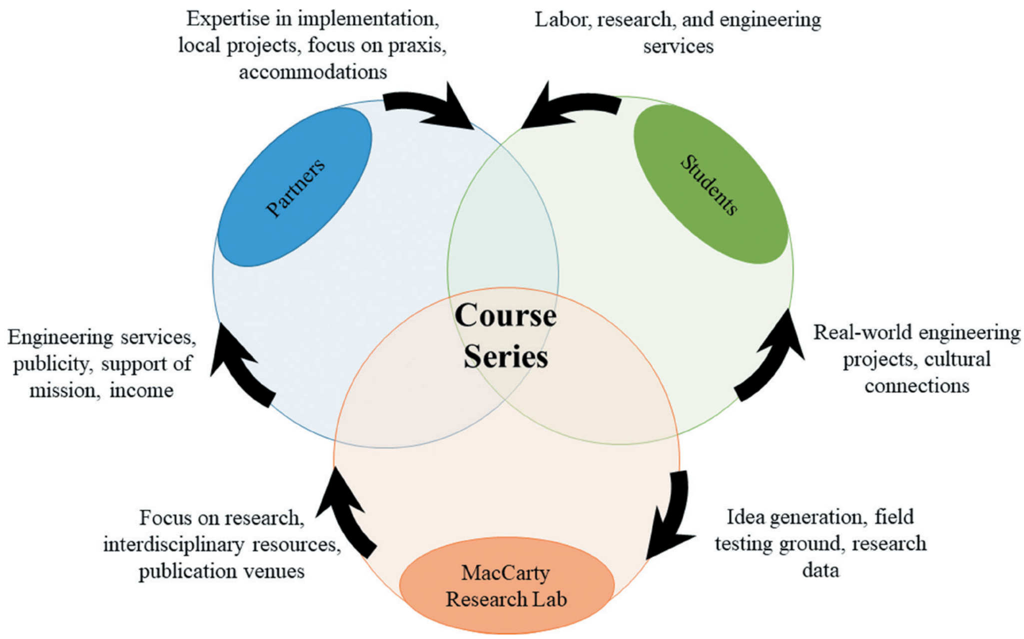

Figure 2. Synergistic relationships between major course stakeholders.

Humanitarian Engineering Program (Figure 2). This long-term collaborative effort helps to ensure sustainability and more effective and lasting results.

MacCarty Research Lab, Humanitarian Engineering Program

As an Assistant Professor of mechanical engineering, MacCarty's goals are to integrate teaching and research while creating opportunities to build the Humanitarian Engineering program. Drawing from nearly 20 years in the clean cooking sector, her current research activities focus on design, testing, impact monitoring, and adoption of biomass cookstoves. To this end, introducing students with fresh perspectives to this field supports her research program through partnerships, in-field data collection, and the recruiting and training of graduate research assistants. Ongoing research in the MacCarty lab supported by the course include 1) data gathering for a National Science Foundation sponsored study #1662485 entitled "Novel Framework for Incorporating Consumer Preferences and Public Goals into Engineering Design Applied to Energy Technologies" (Pakravan and MacCarty, 2020a; 2020b); 2) development and testing of a protocol to quantify cookstove usability during the design phase to support increased adoption (Moses and MacCarty, 2019; Moses, Pakravan and MacCarty, 2019); and 3) development of new and improved sensor-based method to quantify cookstove impacts in terms of adoption and fuel savings (Ventrella, Lefebvre, and MacCarty, 2020; Ventrella, Zhang and MacCarty, 2019; Ventrella and MacCarty, 2019).

StoveTeam International, Eugene, Oregon

StoveTeam International is an Oregon-based non-profit, international development organization whose mission is to help address energy poverty in Latin America. For over a decade, StoveTeam continues to promote the production of cookstoves in four Latin American countries by partnering with local entrepreneurs to develop solutions to the complex challenges of open cooking fires, disseminating 76,300 stoves to date (https://www.stoveteam.org/impact). Their approach to addressing energy poverty focuses on 1) helping local entrepreneurs to establish locally owned, for-profit cookstove businesses in Latin America; 2) developing and monitoring the impacts of cookstoves designed to meet the needs and demands of local users; and 3) removing barriers to acceptance of clean energy technology through education campaigns, strategic placement of cookstoves, use of stove subsidies, and other cost reduction strategies like carbon credits and microfinance.

StoveTeam participates in multiple outreach events each year and regularly hosts service-learning trips for volunteers and students. Participating group itineraries may include cultural exchange, Spanish language immersion, leadership training and development, storytelling, photo-journalism and videography. In keeping with StoveTeam's mission of bringing stoves to communities and supporting local factories, StoveTeam requires each volunteer to support the cost of purchasing and distributing two Ecocina cookstoves (Figure 3A, http://www.stoveteam.org/projects/our-stove).

Figure 3. A) Ecocina cookstove (left) and B) EcoPlancha cookstove (right). Photo credits: Lynn Johnson.

EcoComal Cookstove Factory, San Antonio Aguas Calientes, Guatemala

The EcoComal family-owned and -operated factory was one of the first factories started by StoveTeam, dating to 2010. The factory manufactures several models of cookstoves, including the Ecocina (Figure 3A), EcoPlancha (Figure 3B), and an institutional sized cookstove. The Ecocina cookstoves sell for US$68. Many sales rely on subsidies from outside donors such as Rotary International and other private foundations to reduce the cost to households. The factory manufactures between 3,000 and 5,000 cookstoves each year and employs 32 to 40 workers depending on demand.

Link4 Social Design Enterprise, Guatemala City & Santa Catarina Palopó, Guatemala

Trained in the D-lab co-design curriculum at MIT (d-lab.mit.edu; Sanders and Stapper, 2013), Link4 pairs students from global universities with local residents for immersive project-based design experiences. These workshops teach skills and mindsets for design thinking and co-creation by working on real problems, while merging local know-how and professional knowledge (link4.gt). Students experience local culture while living with homestay families, allowing both students and residents to participate in family life and build empathy and mutual understanding. Working in the small rural community of Santa Catarina Palopó on the shores of Lake Atitlán, Link4 provides sustainable housing, household energy technologies, and fosters local innovation. Link4 works closely with local stakeholders to develop their capacity for innovation and the creation of technologies and other solutions that improve livelihoods, operating on the belief that innovation developed with and by communities is far more effective than those that are simply applied/delivered to a community.

Learning Objectives

The philosophies outlined above support the student learning objectives (Table 1) that seek to introduce students to the practices and challenges of global non-governmental organizations

Table 1. Course Learning Objectives.

- HEST 241/541 Background course
  - Describe the household energy needs of a low-income community within their greater social, economic and environmental context.
  - Apply interdisciplinary theories and practices to consider potential outcomes of different interventions.
  - Develop relevant and culturally-appropriate survey questions or monitoring techniques to assess these theories during field experience/in-country program.
  - GRADUATE STUDENTS: Conduct a review of the literature on a pertinent topic of their choosing and develop related questions for further research.
- HEST 242/542 Field course
  - Demonstrate knowledge of the household energy needs in rural Guatemala
  - Evaluate the effectiveness of sustainable energy technology designs.
  - Apply problem solving and critical thinking in unfamiliar and challenging situations.
  - Use cross-cultural communication for engagement and interaction with rural communities.
  - GRADUATE STUDENTS: Plan and implement monitoring and evaluation techniques in a real-world setting.

devoted to poverty reduction efforts. These objectives aim to increase students' social and cultural competencies and their understanding of historical and contemporary contexts of specific global settings, as well as to develop skills to holistically evaluate the impact of technologies in culturally distinct communities. While the course series does not fulfill major degree requirements, it does count toward the experiential learning requirements for the humanitarian engineering minor.

Impact Objectives

In addition to providing students with real-world research opportunities, an important goal of the course series is to contribute to ongoing research and activities of the partners, and where appropriate, provide partners with needed labor, expertise, and in some cases, credibility or third-party evaluation. Examples of project requests from partners include:

- **StoveTeam**
  - *Stove distribution and impact assessment* – In a project funded by the Portland, Oregon chapter of Dining for Women, 400 cookstoves were purchased and distributed in two remote communities in Honduras. The funding organization's goals were to reduce the burden of cooking on women and children and to increase school attendance. As a result, the organization sought data regarding the impacts of the cookstoves in these areas at the conclusion of the project. The 2016 OSU HEST program helped with survey instrument development and data collection.
  - *Stove usage monitoring* – In 2016, a field study was underway on the adoption and uptake of fuel-efficient cooking technology using temperature sensors or Stove Use Monitors (SUMs) in Las Brisas and San Ramon, two isolated indigenous communities about two hours from the EcoComal factory in Guatemala. This before-and-after study was funded by the US Environmental Protection Agency and Winrock International, with technical support from Berkeley Air Monitoring Group (Laughlin and Garland, 2017). StoveTeam requested assistance with the study methodology, qualitative and quantitative survey design, use of SUMs, and the interviewing of primary cooks in households regarding their cooking habits.
  - *Community mapping* – In an effort to expand stove distribution into new communities, StoveTeam, in partnership with the municipality of Alotenango, sought to conduct interviews with household cooks to better understand household demographics and cookstove needs in the region. These semi-structured interviews were based on standard questions in the field and drawn from previous surveys published and implemented by the partners (Pakravan and MacCarty, 2020).
- **EcoComal Factory**
  - *Cookstove testing reports* – Standardized third-party testing is important for cookstove manufacturers to be able to report on the performance of their stoves. In 2016, the factory

had developed the new EcoPlancha III cookstove model. Given MacCarty's expertise in cookstove design and testing, Marco Tulio, the factory owner, requested that students perform standard testing and safety evaluations on the EcoPlancha III cookstove model.

  - *Cookstove manufacturing* – The small family factory operates on a limited budget and requires flexibility of staffing to accommodate orders, so labor contributions from visiting volunteers are needed and appreciated.
  - *Factory layout efficiency assessment* – In 2016, the factory owner requested an engineering assessment of the efficiency of the factory layout to determine if improvements could be made.

- **Link4**
  - *Co-design of gasifier cookstoves* – Co-design is the activity of designing solutions "with" the community, rather than "for" the community. Previous co-design efforts in the community with Link4 have identified gasifier cookstoves as a potentially viable solution for residents who indicated that they prefer to cook with a prepared fuel such as pellets made from wood waste rather than continue to collect wood from nearby forests. Gasifier cookstoves operate differently than direct burning cookstoves as they operate on a batch-loaded basis. This left a design need to determine the size and features of potential gasifier cookstoves that would meet cooking needs in the region. Therefore, Link4 led a three-day co-design workshop with teams of students, course leaders, and local cookstove users through problem definition, prototyping, and testing.
- **MacCarty Research Lab**
  - *Understanding clean technology adoption* – A research goal in the humanitarian engineering lab is to better understand the determinants of adoption of clean technologies such as cookstoves, and to determine what design and programmatic attributes lead to greater uptake of these beneficial technologies, which have a history of limited adoption. The Theory of Planned Behavior is one framework that can contribute to this analysis and research in this area is supported by a grant from the National Science Foundation (CMMI #1662485) entitled "Novel Framework for Incorporating Consumer Preferences and Public Goals into Engineering Design Applied to Energy Technologies."
  - *Sensor-based impact monitoring* – Accurately quantifying impact of technologies placed in homes is a major challenge in the cookstove sector, where stove stacking is common and survey data often suffers from social desirability or Hawthorne bias (Thomas et al., 2013; Wilson et al., 2015). Few sensors currently exist to provide transparent and unbiased data or measure important metrics such as fuel savings.

Additional objectives intended to directly benefit the participating communities include:

- Subsidizing and delivering clean cookstoves to local families.

Table 2. Background Course Syllabus.

Week	Topic
1	Introduction to Household Energy Poverty
2	Energy Technologies
3	Needs assessment and co-design: Guest Lecture, Link4
4	Quantitative Evaluation: WBT, CCT, FUEL, Usability, Sensors
5	Ethnographic and Qualitative Evaluation: Guest Lecture, Anthropology Students or Faculty
6	Economic Development: Guest Lecture, Dr. Elizabeth Schroeder
7	Guatemala and StoveTeam: Guest Lecture, StoveTeam
8	Culture and Context
9	Student research plans and Research with human subjects
10	Pre-departure orientation

- Employment opportunities for local women to participate in the course activities, including testing at the EcoComal factory and co-design activities with Link4.
- Economic and cultural benefits through homestays and support of local businesses.

Background Course

The prerequisite background course is designed to provide an overview of the issues, technologies, tools, and disciplines associated with the design and implementation of household energy poverty reduction programs (Table 2). The course content is delivered by the instructors, partners, and interdisciplinary experts from across campus in order to provide necessary context and insights from their subject areas that are critical to student understanding of the big picture of energy development initiatives. The role of instructors is to frame the issues, facilitate team building, inspire questions and ideas, and suggest potential areas for research projects.

In-person and online meetings with the partners at StoveTeam and Link4 provide students an opportunity to meet the people with whom they will be working, learn about their organizations and their mission and the tentatively planned activities, and what to expect in terms of accommodations, meals and transportation. In addition, the group discusses logistics such as what items to pack and culturally-appropriate behaviors. The students also participate in an optional field trip to nearby Aprovecho Research Center, a leading global cookstove design and testing firm, to observe a wide variety of cookstove models, learn standardized testing practices, and develop contextual understanding of the cookstove sector.

A main objective of the background course is to complete the selection and planning of in-country research projects for students in teams or as individuals. After being introduced to the issues, active research areas, partners, and in-country objectives in the first half of the course, students are expected to propose a self-directed research topic by mid-term. This project can be selected from a list of activities that have been identified by the partners as goals for that time period, such as performing controlled cooking tests or conducting specified interviews in households. Or, the research can be dictated by the student(s)' own interests, such as monitoring water quality in homes or quantifying energy expenditures in households. The students receive feedback from instructors, and in some cases partners, on their proposals, and then spend the remainder of the term learning the tools and methods needed to execute the research. These include training in ethics of working with human subjects and demonstrations of emissions and use monitoring equipment at the Aprovecho Research Center laboratory. At the end of the term, a detailed research plan including timeline, supplies, and necessary instruments is required and assessed.

The important role of reflection in any type of experiential learning including cultural immersion or study abroad is well documented. The 2018 course series involved a study abroad practitioner (Walkin) who also served as a co-leader and co-facilitator during the course series in 2018 and planned 2020 offering. Drawing largely from frameworks such as Kolb's experiential learning theory, Mezirow's transformational learning theory, and Hofstede's theory of cultural dimensions, Walkin facilitated a number of activities and exercises intended to foster self-reflection and shared meaning-making. Examples of these individual and group activities during the background course included:

- Group introductions that included reflecting on pressing issues and concerns in one's hometown and imagining how a group of visiting humanitarian engineers might engage with the topic.
- Viewing three documentaries/films about the challenges of surviving in a low resource setting (set in Guatemala), a documentary about the unintended consequences of humanitarian aid efforts, and a narrative fictional drama based in a rural, Kaqchikel community in Guatemala, each followed by post viewing discussions.
- Conducting an 'autoethnography' in which students and program leaders are asked to assess their own cultural background and identities and how each aspect informs, impacts, and influences one's way of experiencing and being in the world.
- Surveying students about their expectations, motivations, and trepidations about travel itself, the program, and the project ahead and compiling results in a Wordle format and then discuss.
- Inviting a guest speaker (fellow university student) from the host country to speak to the class and participate in a 'cultural values continuum exercise' with the class that explores cultural patterns across individuals, communities and nationalities (Kappler, Cohen, and Paige, 2009).

Field Course

The in-country logistics and research-related activities for the field course are arranged by StoveTeam, Link4, and their local contacts. Details of logistics and safety plans may be found in the appendix. At OSU, most faculty-led programs are co-administered by the Office of Global Opportunities (OSU GO) and the sponsoring academic unit. In the case of the 2018 program, U.S. Department of State travel advisory for Guatemala was elevated to Level 3 which compelled OSU to develop a risk assessment and corresponding safety plan in partnership with the faculty leaders and in-country program providers (in this case, StoveTeam and Link4) that have extensive knowledge, experience and networks. OSU GO also provides a wide range of pre-departure learning content to support student and faculty leaders with their preparations and while abroad.

Course fees varied from $1,700 to $2,000 per person and covered all in-country accommodations and logistics. Graduate or undergraduate tuition for the spring and summer course sessions was also required. Financial aid could be applied to cover these costs. In some cases, fellowships were available from the Evans Family Fellowship program in the OSU humanitarian engineering program, and were awarded to three students to cover the in-country program fees.

The content of the field course is organized around enabling student participation in achieving the goals of each partner organization previously discussed. An example itinerary is shown in Table 3, showing that the trip is balanced with increasing immersion. The experience begins by spending time in the EcoComal factory assisting with manufacturing and conducting standardized testing, traveling to a partnering community to conduct sensor-based monitoring and surveys, and then ends by participating in homestays and co-design activities in yet another partnering community and region of Guatemala.

During the course, students work in the full group for some activities (in some cases led by a smaller group in charge of that as research), or in smaller groups depending on the activities. The instructors and/or partners assist the teams with the specific projects as needed and are present throughout; however, the students are expected to lead the activity. Descriptions of these activities follow:

- **Cookstove manufacturing** – the Ecocina cookstoves manufactured by the EcoComal factory are made primarily of cement and ceramic with some metal parts. The cement molding and

Table 3. Field Course Itinerary.

Day	Activity
1	Arrive in Guatemala City
2	Travel to Antigua to work with the EcoComal factory
3–6	Performance and usability evaluations, manufacturing, surveys, sensor-based monitoring in partnering communities with **StoveTeam**
7	Travel to Santa Catarina Palopó - Introduced to Host Families
8–11	Co-design activities with **Link4**
12	Return to Oregon

finishing process is labor intensive and includes mixing and pouring cement, opening and cleaning molds, curing in a water bath, and detailed finishing work on the stovetop after the insulated combustion chamber has been installed. Students assisted with each phase of this work on a production line.

- **Controlled cooking tests** – Designed to quantify the time, fuel, and emissions savings when cooking on the improved versus traditional stoves, Controlled Cooking Test (CCTs) require that a cook prepare the exact same recipe three times each on both stove types (Bailis, 2004). In this test series, six cooks were asked to prepare a meal of rice, beans, and tortillas six times each over the course of three days. The team brought several pieces of equipment for emissions testing, including the Aprovecho Research Center Portable Emissions Monitoring System (PEMS) to quantify the total emissions, and Indoor Air Pollution (IAP) meter to monitor the air quality and personal exposure of the cooks. Managing the CCT process for six cooks while providing pre-weighed ingredients, and keeping track of time and fuel use is a challenging task that allowed students to practice their managerial, organizational, and experimental skills. It also gave them the opportunity to observe and participate in cooking traditional Guatemalan cuisine, including shaping corn tortillas by hand.
- **Household surveys** – after having compiled a list of relevant questions, translating them into Spanish, and incorporating them into a web-based survey app, students split up into teams of 3–4 to visit households in each community and conduct the ~15-minute surveys. This provided students the opportunity to observe household structures and resources, cooking environments and practices, and family and social dynamics while collecting meaningful data for the projects.
- **Co-design projects** – Drawing on the methods developed by MIT and honed over several years of International Design Development Summits (IDDS), co-design activities pair students with community members in teams designed to be diverse in background and skill sets. The teams then stepped through a series of activities including empathy-building, problem definition, prototyping, testing, and presenting their designs to a group of cooks (household stove users) for feedback.

Students were welcome to pivot and adapt as needed based on resources and findings in the field. Follow-up after the activities occurred whenever possible, and varied with the projects. These could be as simple as providing a report to the partners on the stove performance or factory layout analysis, or, lead to activities for a future course offering such as the co-design project, or as extensive as developing and testing an entirely new sensor for monitoring household fuel consumption. The most relevant of these are discussed in detail in the Impact Outcomes section.

Reflection was also a component of the field course and was fostered through a daily journal and photo entry assignment supported by the "Journaling Across Cultures" learning module provided to the students in advance (Morais, Ogden, and Buzinde, n.d.). Several facilitated de-briefs and ‘sharing’ sessions took place either at the end of the day or following a particularly intensive experiential learning activity. In addition, at the conclusion of the course, an optional group reunion at one of the instructor’s homes is hosted with a traditional Guatemalan meal to provide time for student reflection and sharing.

Student Assessment

Students are assessed primarily based on their active participation in both the background and field courses (40–50%), and their proposed and executed research (40–50%). During the background course, emphasis is placed on identifying a specific set of research questions related to the topic, identifying the tools needed, and ensuring that any equipment that will be needed in-country is transported by the student teams. The research project is evaluated based on a written proposal and plan, graded on a scale of 0–100% for level of detail and critical thinking and adjusted based on the class standing of the student. Research expectations for graduate students are higher, whereby a literature review takes the place of more than half of the participation points. While in country, the grade is split equally between participation and research for both undergraduate and graduate students. In both cases, participation is defined as being actively engaged in discussions, activities, group work, and peer learning and is evaluated on a scale of 0–100% several times throughout the course. A final research summary and report is due several days after returning from the trip. This report is graded, and revised if needed before sharing with the partners and future cohorts if appropriate.

PROGRAM OUTCOMES

The areas through which the success of this course series is evaluated include 1) Enrolling a diverse student cohort from multiple disciplines; 2) integrating learning objectives that lead to achieving the NAE Global Competencies; and 3) evaluating impact outcomes for the partners and target communities.

Enrollment

The course series is promoted campus-wide through the Office of Global Opportunities to students in any discipline or major and at any degree level. The College of Engineering also promotes the course extensively with college-wide communications as well as outreach to students, advisers, and faculty affiliated with are in the humanitarian engineering program, the OSU chapter of Engineers Without Borders. Several informational meetings are held during the 6–9 months leading up to the application deadline. No targeted recruiting based on select demographics was conducted. In aggregate, the courses in 2016 and 2018 secured participation from a total of 25 students from the College of Engineering (68%) (mechanical, chemical, civil/construction, electrical/computer, ecological and nuclear), the College of Liberal Arts, (24%) (public policy, economics), and College of Education with 4% each mathematics and science education. The majority of students were Seniors (36%), followed by Juniors (20%), Sophomores, Masters and Doctoral students (12% each), and finally first-year students (4%). All but one student was degree-seeking. Gender breakdown was 60% female and 40% male. The 60/40 female to male gender ratio is unusual for traditional engineering courses, but is fairly typical and consistent with other humanitarian-type coursework opportunities (Dzombak, Mouakkad, and Mehta, 2016; Skokan and Gosink, 2005; Paterson, Swan and Bielefeldt, 2016).

Roughly one-third of the participating students were financial aid eligible. Three students (12%) were partially funded by Evans Family Fellowships provided by the humanitarian engineering program to cover the course fees. For many students, this was their first time traveling internationally; and for one student, it was their first time traveling by airplane. Others had traveled abroad extensively or had participated in a student exchange program in high school. Approximately 28% of the students had functional Spanish language skills that enabled them to communicate directly and also help to translate for others. Several (28%) of the students were either previously involved or went on to join the OSU chapter of Engineers Without Borders, indicating a commitment to international development. This diversity of experience enabled peer support and learning.

With respect to the program leadership, it should be noted that all three of the faculty leaders identify as non-Hispanic white females who are experienced international travelers and able to offer distinct areas of expertise. They are not necessarily content experts of Guatemala's political, economic, social and cultural context, nor fluent Spanish speakers. This illustrates the increased importance of the role of bi-cultural and bilingual community partners who not only significantly enhance the learning with their local knowledge, but serve as a bridge to engage with more diverse communities where additional language and cultural barriers may exist. This bridge was provided by the StoveTeam leadership (U.S. national females with extensive experience living and working in Latin America), Guatemalan EcoComal factory owners (Guatemalan nationals), and Link4's facilitators (Guatemalan nationals).

It was commonly heard from students that the opportunity to work with different majors and professionals from different backgrounds was welcome and insightful, and broadened perspectives for everyone. One student appreciated "*the idea of being with a group, of having to hear all of these different opinions and thoughts and consolidate them into one plan*." The balanced blend of first year through graduate students was also helpful as graduate students effectively role modeled more rigorous research projects and behaviors for the newer students in an accessible manner. At the same time, undergraduate students were available to assist graduate students with their data collection.

Student Outcomes

In 2018, an engineering education researcher (Aster) accompanied the group and collected observations and semi-structured interviews with eleven consenting students to explore how the experiences affected students' learning, confidence levels, and approaches to the challenges they encountered. Transcripts from the 11–25 minute interviews were coded using Dedoose analysis software and a combination of inductive and deductive coding procedures. The research was overseen by OSU IRB study number 8541 (Aster et al., n.d.). Analysis revealed several themes, including a better understanding of:

- Confidence in conducting engineering field research and broadening one's research skills.
- The need for flexibility in field research and ability to adapt to fluid/uncertain situations.
- The benefits and limitations of humanitarian development aid and subsidies and the role of non-profit organizations.
- The importance and challenges of language barriers and social dynamics.
- Discovering commonalities with people and appreciating cultural/resource differences, breaking down stereotypes.

Also in 2018, an OSU study abroad professional and course co-instructor (Walkin) assigned a daily writing and photo exercise guided by "Journaling Across Cultures", a learning module developed by Morais and Ogden (2009). Themes from journaling revealed similar findings as the interviews described above, including:

- How first-hand exposure to low resource environments stimulates new considerations when identifying engineering solutions.
- How rewarding it is to connect with people (local community members) even as language and 'cultural context' barriers exist; and simultaneously, how frustrating and limited one's effectiveness is/feels when language and 'cultural context' barriers exist.
- How an education abroad experience focused on service- and project-based learning can reinforce the value and importance of pursuing a career in humanitarian work and engineering.
- Presence of conflicting thoughts and emotions with the recognition of economic disparities between countries and regions; privileges of being a visiting university student from the U.S.

Select excerpts from student journals that highlight these findings are included in the text box. Throughout the program, program leaders facilitated group reflection exercises, enabling students, program leaders, and local partners an opportunity to share their observations, feelings, reactions, insights and questions to further examine or to take into consideration.

QUOTES FROM STUDENT PARTICIPANT JOURNALS:

"We built a small cardboard prototype (complete with a tea pot and tortillas!) and went to interview a few of our host families on what they thought of the design. After getting some feedback about those designs, we factored them in and then went to work on our full size prototype.... It is a lot of work building a prototype out of cardboard! It's also a lot of working trying to balance the voices and opinions of six people with diverse knowledge, experience, and perspectives. After that, we presented our prototypes to our moms. It was neat seeing how they gave more and more feedback throughout the design process. It might be because they had more time to think about it, but I think a part of it was growing the trust between the students and families, and possibly that ***asking over and over made it clear that we really did value their feedback****." (female student on program)*

"It was a lot more difficult to leave the host family than I had anticipated. They are such special people to welcome us into their home and treat us the way that they had. Without even knowing it, they had taught me to really appreciate what is available to me and the countless opportunities that I have. They gave me a new and very personal perspective on why including humanitarian work in my career will be necessary and fulfilling." (male student on program)

Day two of the program involved a spontaneous decision to have the group drive through the region impacted by a volcanic pyroplastic blast that occurred four months earlier in June 2018: "It became clear that many of us on the trip felt weird and "guilty" about being tourists in a region that had been so devastated. I continuously thought about the genocide course that I took my senior year of high school and the discussions that we had in that class about how people should act while visiting places of such tragedy. I think that we should feel no guilt about seeing the effects of Volcan Fuego first hand as long as we are to do so with the correct attitude and intentions. The severity of the eruption and the lives lost must be respected and thought of in terms of a loss of humanity, not just numbers. The thoughts passing through our heads should be "Why were the effects so devastating?" and "How can this be prevented in the future?" rather than simply "Woah, this is crazy" because ***while it may never feel quite right to be there in our situation, there is no guilt in furthering one's understanding****." (male student on program)*

Other student outcomes included increased involvement with Engineers Without Borders, many in leadership positions. One student joined the Peace Corps after graduation and another switched from a career in nuclear engineering to pursuing solar energy policy by securing a position at the National Renewable Energy Laboratory (NREL). Because the course was also open to graduate students, several graduate students were able to use the experience to formulate or write their Master's thesis or essay. This included two public policy students, one of whom wrote a paper entitled "Impact Evaluation in the Field: A Case Study on the Evaluation of an Improved Cookstove Initiative in Rural Guatemala" (Nilson, 2017) and the second whose thesis title is "Impact of Electricity Access on Women's Poverty (Using a Proxy of Time-use) in Central America" (Duvall, 2019). The dual master's thesis in mechanical engineering and applied anthropology and corresponding journal articles regarding the development of the FUEL sensor discussed below were also an outcome of this course (Ventrella, 2019; Ventrella and MacCarty, 2019a; 2019b; 2020).

Impact Outcomes

Further to the student outcomes, long-term impacts for partners and communities were also achieved in terms of advancing both knowledge and praxis.

StoveTeam International

Students and faculty contributed to larger, ongoing efforts at StoveTeam that include:

- **Research/data collection** – Participation in the ongoing field studies on the adoption and uptake of fuel-efficient cooking technology using temperature sensors or Stove Use Monitors (SUMs) (Wilson et al., 2016). Upon invitation into community members' homes, students recorded general observations and took photographs of open fires, new cookstoves and the SUMs placement on both the open fires and the intervention stoves. The results of this study have been used to advance the field of cookstove research more generally, including the scientific validity of SUMs placement in the field as a means of measuring adoption (Laughlin and Garland, 2017). StoveTeam has shared the results of the study with private funders and individual donors to illustrate the impact of clean cooking technology.
- **Community mapping** - In 2018, OSU students participated in mapping the community of Alotenango, Guatemala to help StoveTeam determine the need for and interest in fuel-efficient cooking technology. Students visited 20 homes and conducted observational and qualitative surveys with the primary cook of each household, via an online survey instrument called Magpi. The data collected indicated the types of stoves already in use, the areas of need, and have informed StoveTeam's future projects in the area.
- **Social network analysis** – The NSF-funded research project on the determinants of adoption of clean technology also considered social network analysis and agent-based modeling based on data collected with StoveTeam in Guatemala and Honduras. The findings of this research indicate that high-density placements of cookstoves may be more effective than distributed

placements due to the influence of social capital in the communities (Pakravan and MacCarty, 2021). StoveTeam has indicated that they will experiment with such placements in future distribution efforts.

- **Publicity and community engagement in Oregon** – Highlighting affiliation with university students and faculty in their promotional material and credentials helps to maintain and build the credibility of the organization, and provide research and spotlight stories for their newsletters and online presence that aid in securing funding and volunteers.

EcoComal Factory

Through this program, students were able to participate in the manufacturing of several dozen cookstoves to fill orders based on StoveTeam grants as well as the stoves subsidized by the OSU group. Third-party performance testing services for the EcoPlancha III (Figure 3B) was also provided. Given MacCarty's previous role as laboratory manager for the leading global testing firm and her participation in standardized testing protocol development (Bailis et al, 2007; ISO, 2018), the OSU students were able to provide this service with guidance. Case in point, for the open fire, Ecocina, and EcoPlancha III, standardized Water Boiling Tests (Bailis et al, 2007) and Controlled Cooking Tests (Bailis et al., 2004) were able to be performed by the student teams. At the same time, additional student teams followed published safety testing protocol (Johnson and Bryden, 2015) and usability testing protocol (Moses, Pakravan, and MacCarty, 2019; Moses and MacCarty, 2019) that was under development in the MacCarty lab to evaluate the safety and usability of the stoves as well. The teams prepared a report detailing the results of these tests for the factory following standard reporting metrics and methods in the sector, and compared them to the ISO IWA guidelines (ISO, 2012). Recommendations for stove design improvement were also provided.

Conversations with the factory leadership during the background course also inspired one student team to conduct an evaluation of the industrial workflow analysis in the factory using industrial engineering tools that outline suppliers, inputs, processes, outputs, and customers for a manufacturer. Following the principles of 5-S (sort out, straighten, scrub, standardize, and sustain) (AME, 2014), an analysis was conducted to help eliminate waste, organize current processes, clean-up work areas, standardize current processes, and develop a long-term culture and system to follow lean manufacturing procedures. In addition, process flow mapping (Rother and Shook, 1999) was conducted and a diagram of the factory was made in Google SketchUp. These detailed analyses were discussed with the factory leadership while in-country, and a report (in English) was provided to them and StoveTeam at the end of the trip that included recommendations such as re-locating inventory for easier access, batching inventory, and re-allocating employees between stations as needed to limit waiting for work-in-process materials.

Link4

Link4 reported that ngaging with the course provided important learnings and insights on cooking dynamics and usability preferences of community members. During the co-design activities, one team identified a retained heat cooker as a promising design alternative to meet the user objectives. This technology seemed to perform well and be promising to the cooks, and was going to be the subject of a community maker space activity with students during the planned, but later cancelled, 2020 trip. This ultimately led to the creation of a remote collaborative co-design course developed with Link4 for the Spring 2021 quarter at OSU, continuing to build on this topic and partnership. The prototype gasifier cookstove designs that were developed during the course also contributed significantly to the thesis of Marcos Vielman, an engineering graduate student at Universidad del Valle in Guatemala City who was collaborating with Link4. He further developed some of the designs and built a functional prototype of the gasifier cookstove. In addition, the large class size of participants enabled Link4 to expand their network of families participating in homestays and other co-design and sustainable design activities.

Community

Through StoveTeam's outreach efforts to communities in greatest need, and cookstove purchase requirements for the course alone, sixty-six cookstoves were distributed in 2016 in Las Brisas and San Ramon, and in 2018, twenty-eight cookstoves were distributed in Alotenango. The partners at EcoComal and the broader network of StoveTeam factories across Latin America distribute and help install cookstoves in the tens of thousands independently from the course as well.

Co-design and homestay activities with Link4 in 2018 resulted in a meaningful experience and cultural exchange for both the host families and the students. Sharing meals and chores, holidays, stories of family life, and thoughts on politics with indigenous Kaqchikel- and Spanish-speaking families showed how many similarities there are between people coming from such different backgrounds. This provided benefits for the students as well as the families, many with children. Payment for room and board also benefitted each participating household.

MacCarty Research Lab

Collaboration for the courses also supported broader research projects between the partners which ultimately led to publication of eight peer-reviewed conference proceedings and five journal papers published described below.

- **FUEL System development and testing** – Perhaps one of the most impactful outcomes to come from the collaboration was the conceptualization, development, and testing of the Fuel, Usage and Emissions Logger (FUEL) system for quantifying the impact of cookstove projects.

During the first iteration of the course, graduate student participant Jen Ventrella noted that standard practice in the sector was to use SUMS temperature sensors to monitor stove body temperature as a proxy for use. However, these are cumbersome in the field, requiring laptops to launch and download, are failure prone, and interpreting the data was challenging due to the long heat-up and cool-down periods. Most importantly, the sensors do not measure a key indicator of impact, which is fuel savings. Based on Ventralla's observations during the course, she hypothesized that creating a sensor to monitor fuel use would provide a useful tool for the sector. In partnership with StoveTeam and another NGO in Uganda, the FUEL system was subsequently designed (Ventrella and MacCarty, 2020; Ventrella, Zhang, and MacCarty, 2018, 2019), tested (Ventrella and MacCarty, 2019; Ventrella and MacCarty, 2018), and validated (Ventrella, Lefebvre, and MacCarty, 2020). To commercialize this system, the broader design team participated in a business accelerators program at Oregon State and through the NSF I-CORPS program (grant #1755524), and, in addition, received stage 1 and 2 funding from the VentureWell student entrepreneurial team program (venturewell.org). Commercialization efforts for this system continue with extensive monitoring research planned in the near future that includes being part of a $1M grant from the Canadian government through the Alliance for Clean Cooking (cleancooking.org). The project will monitor usage and emissions of several types of stoves and fuels in urban Haiti as part of the Haiti Action Plan (Global Alliance for Clean Cookstoves and Global Affairs Canada, 2017).

- **National Science Foundation (NSF) Sponsored Research** - Demographic and technology adoption-related data collection and methods for an NSF supported project were developed in the 2016 course. Data collected with StoveTeam's project in Honduras, while only indirectly associated with the field course, led to three peer-reviewed conference papers (Pakravan and MacCarty, 2018; Pakravan, Laughlin, and MacCarty, 2018; Pakravan and MacCarty, 2019) and three journal publications (Pakravan and MacCarty 2020a; 2020b; 2021). Outcomes have also resulted in the development of methods that generated a second wave of field testing in Uganda, whose results may be used by StoveTeam in the future distribution of cookstoves to increase adoption rates.
- **Usability protocol** - The second iteration of the trip allowed for a student-led field test of a newly-developed protocol for evaluating cookstove usability (Moses, MacCarty, and Pakravan, 2019). This initial feedback from the field helped the authors to refine and improve the protocol, and secure a larger sample size and locational pool to draw from and publish (Moses and MacCarty, 2019). It is hoped that this protocol will help bring usability to the forefront of the design process for cookstoves, which currently tends to focus on technical performance.

A few major takeaways for others looking to implement similar programs in the future include:

- Provide opportunities for as many diverse projects as possible that may resonate with partner and student interests. Students often have specific interests and goals and the more faculty instructors can tailor the experience to those interests, the more successful the student learning will be.
- Communicate with partners regularly to keep up to date on their objectives, challenges and strategies. These periodic conversations can help identify overlapping interests and avenues for collaboration.
- Focus on the real-world needs and barriers to scaling effective technologies. Often the focus can shift to the nuances of design and testing, but the ultimate objective is to determine what works and then do it on a large scale.
- Use reflections and journaling to tie everything together and help students to synthesize and integrate what they have learned. Time in the field moves very quickly and this helps to demarcate between experiences and helps to get a sense of the student perspective.
- Prepare students in advance to approach their research, projects, and every day experiences in country with flexibility and a willingness to adjust plans, along with practicing 'cultural humility' that is especially important for cross-cultural interactions. Highlight the practice of checking one's assumptions and conclusions with alternative interpretations and perspectives. University students typically expect a well-defined if not rigid schedule and planned outcomes in traditional coursework, but these are not always possible in the real world.
- Upon return, hold more structured learning opportunities with the group to unpack their learning experience, e.g. sharing journal entries, distributing the results of their individual and group research projects, and collaborating on a final group presentation to share with target audiences, including program partners and campus stakeholders. This would fulfill the need for students to learn from each other and identify how their thinking has changed as a result of the experience.

CONCLUDING DISCUSSION

Through the two offerings of this course series, there were significant, lasting, and broader impacts for the partners and students beyond simply the direct course-related activities. Major outcomes include a novel monitoring tool developed for the clean cooking sector currently in production; detailed product and manufacturing performance improvement and recommendations reporting for the local factory; 94 cookstoves financed and delivered to families through the courses alone; data collected for four master's theses and one Ph.D.; eight peer-reviewed journal papers submitted/published; five conference proceedings published and presented; and support of reporting to NGO's and their funding organizations. In addition, this course series supported partner organization activities through reporting and publicity, and income generation and cultural exchange within the participating communities.

Lessons learned include the importance of careful research project planning to provide both value to partners and meaningful work for students to engage in while in-country. Students who had identified relevant, feasible, and sufficiently rigorous research projects and were well-prepared for them had more satisfying experiences. However, this preparatory effort should be balanced with the understanding that flexibility may be necessary in the field when timing, situations, or available assistance do not work out as planned. Students were generally not accustomed to the more fluid nature of time and commitments in the local (Guatemalan) setting or the need to adjust plans due to unforeseen circumstances, so it is important to prepare them in advance for these possibilities.

The program is evolving to better incorporate principles of fair-trade learning in future iterations, further solidifying and consciously approaching the partnerships in place. These principles, particularly those centered around dual purposes and community voice and direction, are discussed in a second article about this course in this special issue (Reynolds et al., n.d.). Planned changes for this course to support fair trade learning include holding post-program debriefs with partners, and maintaining communication throughout the year rather than only during course preparation and execution in order to build on each other's goals and aspirations. In addition, more accessible communication modes with the in-country Spanish- and Kaqchikel-speaking partners to communicate and receive feedback on research results are needed.

For programs considering similar activities, practitioners should recognize that co-developed research objectives and experiences are a key to sustainability, impact, and motivation for all parties. Leveraging existing research projects for stakeholders can create synergistic opportunities. Longer-term projections and projects can help solidify partnerships and contribute to sustainability as well. It should also be noted that not all outcomes are specific to the rather brief timeframe of the course itself. An array of other benefits that occur on a longer time horizon are possible, as shown by the research publications and innovations described in this paper.

ACKNOWLEDGEMENTS

The authors are incredibly indebted to StoveTeam International and their staff, particularly Katie Laughlin, Kim Forrest, and Megan Bogart; Marcos Tulio of EcoComal; and the staff and supporters of Link4 including Omar Crespo Cardona, Oscar Quan, and Maria Jose Saenz; Marco and Marcos

Tulio of EcoComal; the homestay families in Santa Catarina Palopó who opened their homes to participants; and all of the students who participated in the courses and shared their feedback. We would also like to thank Dr. Elizabeth Schroeder of OSU's School of Public Policy for her role as co-instructor and course developer in 2016, Dr. Ellen Aster with support and sponsorship from OSU's Dr. Jana Bouwma-Gearhart and Dr. Kendra Sharp for the STEM education research conducted with the students, as well as the Evans Family Fellowship program for student support. We also appreciate the financial and intellectual commitments and enthusiasm from the student participants.

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APPENDIX

Trip Logistics

In Antigua, guest houses with less than 20 rooms are used with 2 students per room. Meals are provided by local restaurants with sack lunches provided for days spent out in the field. During the homestays, two students are assigned to each vetted home and provided with a simple room and access to a shared bathroom. Meals are prepared and eaten with the host families, giving students the opportunity to be a part of the family and learn first-hand how local dishes are prepared and observe how family members use their cookstoves.

Safety Policies

In addition, safety plans are in place based on local conditions. For Guatemala, these include no travel after dark, avoiding Guatemala City, and minimum vehicle safety requirements. Transportation is provided by two dedicated drivers with vans hired by StoveTeam. Local drivers monitor local conditions such as political protests or traffic, ensuring the group arrives to destinations safely without delays and can avoid traveling after dark.