Enhancing Students' Learning Experiences through Translational Research in Engineering Education

Dr. Jennifer Harper Ogle, Clemson University

Dr. Jennifer Ogle is currently an Associate Professor in the Glenn Department of Civil Engineering at Clemson University. She specializes in transportation infrastructure design, safety, and management, and has been the faculty advisor for the Clemson Engineers for Developing Countries (CEDC) program since 2011. During this time, the CEDC program has tripled in growth and has been recognized by the Institute for International Education (IIE) with the Andrew Heiskell Award as a model program, and was also recognized by the State of South Carolina for the Service Learning Award in 2011. Dr. Ogle was also recognized in 2012 by President Obama as a Champion of Change for Women in STEM, and participates in a number of diversity-enhancement programs at the university including serving as the Chair of the Women's Commission and as a member of the ADA Task Force.

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Jeff Plumblee, PhD, MBA is a Postdoctoral Research Fellow in online service-learning at Clemson University. Plumblee founded the award winning Clemson Engineers for Developing Countries (CEDC) in 2009 while pursuing a doctorate in civil engineering. He has helped to grow the organization to 100+ students per semester, including 2-5 interns living in Haiti year-round. The program has overseen in excess of $2 million in sustainable infrastructure and economic development projects in Haiti. He is currently exploring ways to offer similar opportunities to a wider audience, including bringing the CEDC model into a domestic context, leveraging technology to virtually link students with service-learning opportunities and resources throughout the world, and starting a design challenge for high school students to address the needs of the less fortunate.

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David is a Professor of Practice within Clemson University's Glenn Department of Civil Engineering, the Founder and Owner of Integrated Resilience, LLC, he is a former Fluor Fellow, Director of Resilience Solutions, and Secretariat of the World Economic Forum – Disaster Resource Partnership (WEF DRP). He founded and spearheaded development of Fluor's Business Continuity and Disaster Management Services which helped Clients build resilience by mitigating risk to natural disasters. He has more than 25 years of project management experience in diverse industries, including pharmaceuticals, chemicals, oil and gas, steel mills, microelectronics, water treatment, and contingency operations. His experience in rapid deployment, planning, disaster management, and reconstruction is a culmination of his work in support of the U.S. Army Sustainment Command, FEMA, and various private sector companies. David's passion for his profession is demonstrated by his personal commitment to a number of humanitarian projects, including: Serving as a vice co-chair for The Infrastructure Security Partnership to implement strategies that help economically challenged build resilience. Volunteering as the Project Manager as part of the Haiti Relief effort for the Episcopal Diocese of Upper South Carolina (EDUSC). Mentoring Clemson Engineers for Developing Countries students who are assisting the economically challenged people of Haiti. Under his guidance, this team received awards in 2014 from the Institute of International Education and in 2010 from the university and the State of South Carolina for their work. In honor of his support for engineering students who are changing the world, David was awarded the 2012 Martin Luther King Jr. Excellence in Service Award and the 2014 Distinguished Service Award from Clemson University.

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Enhancing Student's Learning Experiences through Translational Research in Multidisciplinary Engineering Education

Abstract

To tackle the societal grand challenges of the 21st century, this article proposes that the concept of translational research has valuable applications within a broad engineering context to better prepare the professionals of the future. Translational research is commonly found in the medical field and closely related disciplines, but there is limited literature pertaining to its use in engineering education despite its suitability for the latter. The proposed translational research and education model has been leveraged in an undergraduate research course with focus on research, design, and implementation of sustainable solutions in developing countries through multidisciplinary service-learning projects. Translational research connects theoretical research with practical implementation, bridging the 'valley of death' between academia and real-world application.

This paper details how translational research can be applied in an engineering education setting, provides a framework for its use, and discusses the benefits to students, faculty, and society. The paper provides highlights of an application of the translational research model at Clemson University in which students in multidisciplinary teams research novel and adapted solutions to societal problems, work through multiple funding sources, and collaborate with community stakeholders to implement infrastructure solutions. The facets of translational research will be defined, as well as differentiated from problem-based learning and service-learning. Initial data supporting the educational outcomes gained from this learning style will be discussed. Overall, the case is made for the expansion of translational research from academic medicine into engineering education, while retaining the core concept of bringing 'theoretical knowledge and experimental breakthrough to practice.'

Introduction

The global society we live in presents today's engineer with many complex challenges to resolve, including the following infrastructure concerns:

- Availability of Clean Water - Water related diseases affect more than 1.5 billion people every year, and nearly 1 million people die each year from water, sanitation, and hygiene related disease.[1] In lower and middle income countries (LMICs) one-third of the healthcare facilities lack a safe water source.[1] A review of rural water system sustainability in eight countries in Africa, South Asia, and Central America found an average water project failure rate of 20 - 40 percent.[2]
- Access to Sanitary Systems – One in three (2.4 billion) people lack access to a toilet. [1,3] More people have mobile phones than have access to toilets.[4] Women and girls living without a toilet spend 266 million hours each day finding a place to go, and suffer health issues from delaying elimination.[5]
- Utilization of Sustainable Energy Sources - 1.2 billion people are without access to electricity and suffer economically and educationally from energy poverty.[6] More than 2.7 billion people rely on the traditional use of biomass for cooking, which causes

harmful indoor air pollution.[6] Each year, 1.9 million people (predominantly women) die from smoke inhalation which causes diseases such as pneumonia, lung cancer and tuberculosis.[7]

- Support for Safe Transportation - More than 3,400 deaths and thousands of injuries occur every day on our world's roads.[8] Currently 90% of the world's 1.2 million road fatalities per year are in low and middle income countries, and by 2020 the number of road fatalities in these countries is expected to grow by 50%.[8] Vulnerable road users (pedestrians, bicyclists, and riders of motorized 2-wheelers) account for half of all road traffic deaths globally.[8]

These and numerous other issues have been defined as societal grand challenges. The breadth, complexity, and interdisciplinary nature of these challenges highlight the need to better prepare today's engineers with the intuition, skills and tools they need to tackle these problems. Charles Vest, [9] former president of National Academy of Engineering, asserts that engineering students prepared for professional careers in the year 2020 and beyond,

> "must be excited by their freshman year; must have an understanding of what engineers actually do; must write and communicate well; must appreciate and draw on the richness of American diversity; must think clearly about ethics and social responsibility; must be adept at product development and high-quality manufacturing; must know how to merge the physical, life, and information sciences when working at the micro- and nanoscales; and must know how to conceive, design, and operate engineering systems of great complexity. They must also work within a framework of sustainable development, be creative and innovative, understand business and organizations, and be prepared to live and work as global citizens. That is a tall order…"

Engineering education has progressed with the introduction of different active learning pedagogies over the years, including project-based learning, problem-based learning, service-learning, and peer-led team learning. However, students are still mostly trained to solve well defined problems which do not reflect the complexities of real-world problems.[10] We propose that translational research can provide a step forward in enhancing engineering education for the 21st century engineer. Vest's description of the necessities for the future of engineering education, the ability to make new discoveries and innovate continually,[9] fits well within the translational research framework, not just driving innovation, but driving innovation to reality.

Translational Research

Translational research connects theoretical research and practical implementation, creating a bridge between academia and professional practice. Translational research is often referred to as a mechanism to span the "valley of death" by moving medical research from the bench to practice where it can be effective in improving health and quality of life. In this article, a case is made for expanding the field of translational research to include engineering and science discoveries. Translational research is commonly found in the medical field and closely related fields, but there is limited literature pertaining to its utilization in engineering education despite its suitability. This paper attempts to show how translational research is appropriate for, and can be applied to engineering education to enhance students' learning experiences and prepare the all-rounded 21st century engineer to meet the challenges of today and tomorrow.

The main objectives of this paper are to show how translational research can be applied in an engineering education setting and to provide a framework for achieving it. The proposed model has already been leveraged in a multi-semester undergraduate research course at Clemson University with focus on creating holistic and sustainable community impacts in developing countries. Through a cycle of three stages (moving between basic research, field testing, and practice ready implementation and cycling back), students from more than 30 disciplines across the university and from all levels (freshman through graduate students) work in teams to innovate solutions to the most critical problems facing humanity in the 21st century using new knowledge from basic research. Translational research is especially appropriate for multidisciplinary work, as it takes numerous expertise areas to move a solution from conceptual research to practical application. Minimal scaffolding is provided by faculty and industry advisors, but strong professional networks are developed with researchers, subject matter experts, practicing professionals, industry partners, funding partners, and community members. A critical role belongs to the undergraduate student engineering interns, who live abroad in the developing country year round on 7-month rotations. The interns provide project oversight in implementation, and are instrumental in ensuring long-term project success and adoption by the local community. The interns also serve as remote field advisors to the numerous undergraduate research teams at Clemson University. Examination of one research-to-practice project showcases the evolutionary process of translational research.

The following sections will provide:

- A definitive explanation of the tenets of translational research in medicine;
- An explanation of the development of the translational research model in a multidisciplinary engineering environment;
- The key differences between problem based learning / service-learning and translational research;
- Highlights of an application of the proposed translational research model; and
- Initial observations supporting the educational outcomes gained from translational research.

Definition of the Translational Research Model

Translational research originated, and is defined and studied within the medical discipline, but its concepts can also be applied to engineering. In medicine, translational research is translating research of 'theoretical knowledge and experimental breakthroughs' into practice. [11, 12] Translational research is essentially the bridge between basic research and applied research. It developed to address the transition from basic research to clinical research and as such is defined as 'transforming research innovations into new health products'.[12]

In 1998, the National Institutes of Health (NIH) funded curriculum development for over 50 clinical research training programs to improve the quality of clinical research and establish degree-granting programs. Since then, the NIH definitions of both basic and clinical research have been widely adopted, and the concept of translational research has emerged. The NIH definition[13] of translational research can be described as a unidirectional continuum of two stages as shown in Figure 1. First there is transference of knowledge from basic research to clinical research (Stage T1), then from clinical studies to practice settings and communities (State T2) – all undertaken with the intent to improve health.

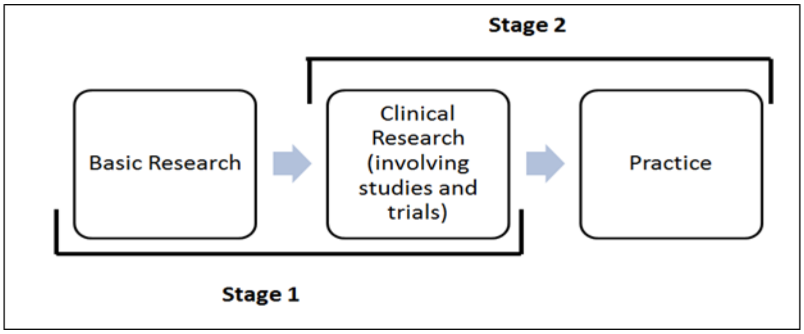


Figure 1: The Initial NIH Two-Stage Unidirectional Translational Research Model

The topic of translational research is getting more attention in recent years, and more defined models [14, 15] of translation are being developed and clarified. The model most closely followed in this research was portrayed by the Evaluation Committee for the Association of Clinical Research Training (ACRT) [16] and includes a third stage component (Stage T3) which completes a cyclical model with bi-directional transfer of knowledge at all stages. An example of T3 knowledge transfer is explained as the use of population-based research to inform basic research hypotheses. Thus, a treatment is developed in the lab and tested in small clinical trials before considering its use with the general population. The cyclical three-stage model is shown in Figure 2.

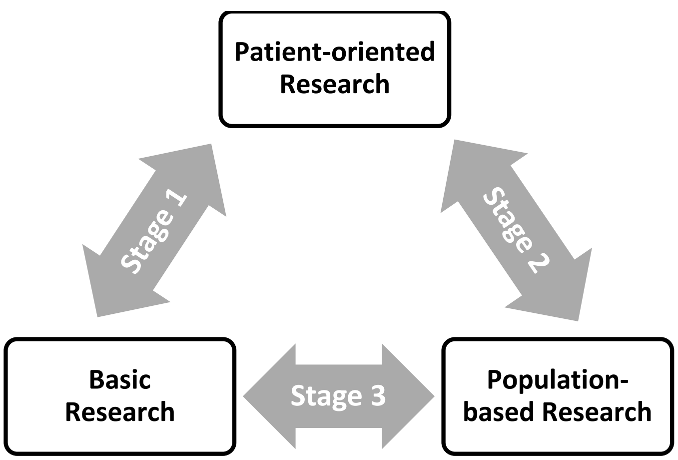


Figure 2: The ACRT Three-Stage Bidirectional Translational Research Model

The ACRT framework also included a list of inputs, activities and outputs as follows:

- Inputs - Financial inputs such as institutional investments, research funding, trainee scholarships, and other federal and private funding; and Human resources such as trainees (theoretical and applied), program faculty and administrators, and mentors from multiple disciplines.

- Activities - Didactic coursework including research methods, discipline specific courses, research management, ethics, scientific communication, and community engagement; Mentored research including scholarly writing, presentation, and publication of results; Cross-disciplinary research collaborations; and Internships in community academic partnerships.
- Outputs - Well-trained and well-mentored translational researchers working in a collaborative, participatory, multidisciplinary environment and linking basic and applied research with community-based resources in a cyclical process.

Like those in the health sciences, in engineering we face critical, complex problems that require timely solutions. Translational research provides this. The aim of translational research is to ensure research and discoveries will not go unused and undeveloped, rather they will produce much needed positive community impacts.

A Translational Research Model for Engineering

The proposed translational research model for engineering has developed from the foundations of a service-learning course (Clemson Engineers for Developing Countries) with the aid of funding from the Clemson University Creative Inquiry undergraduate research program. The resulting program is student-directed and is designed to model a corporate enterprise, which engages in translational research to solve meaningful, real-world problems and create holistic sustainable impacts for communities in developing countries.

The model shown in Figure 3 represents the key components of the translational model for engineering, which includes funding, mentors, students, interns, the community, impacts, and like the above-mentioned models, translational research phases:

Funding - The outer ring represents the requirement for funding, which may include federal research funds, non-governmental organization (NGO) funds, development bank funds, community co-op funds, university funds, tuition, and private funds. Multiple funding partners may provide resources for each stage of the translational research process.

Mentors - The second ring represents the mentors, a mix of academic and practicing professionals that mentor students throughout the translational research process. While some faculty and industry advisors are connected directly to the program, students are encouraged to build their own networks of academic and practicing professionals that can act as subject matter experts (SMEs) at different stages in the translation process.

Students - The third ring represents the students – who are vertically integrated (freshman to graduate levels) and also horizontally integrated (across numerous disciplines). The training outcomes for students include development of research methods, critical thinking, and professional skills such as multidisciplinary teamwork, leadership, communication, and entrepreneurship. The inclusion of a multitude of disciplines provides diversity of thought and a more holistic view of both the problems and solutions.

Student Interns - Beyond the translational research process are the student interns. The adoption of the research outcomes into both the field and community practices is cultivated and supported by the student interns living in the host community. They provide a consistent and much needed connection between the community, practicing professionals, students in the classroom, and academic researchers. The interns must constantly engage on both sides to ensure that the community is knowledgeable about the processes, expected outcomes, and will be able to sustain projects after implementation. In addition, the interns provide feedback to the research and implementation partners to drive holistic sustainable impact in the community.

Community – The community refers to the group or area associated with the initial field tests and includes a larger population or area that may benefit from widespread adoption of innovative practices. It is essential that the community members cooperate and contribute to the translational research process to achieve maximum benefits and ensure long-term sustainability of the projects and impacts.

Impacts - The ultimate outcome of the translational research model is positive community impact created by multidisciplinary teams working together to make new discoveries drive innovation to practice.

Translational Research Phases - The translational research process is represented in three phases, much like the ACRT medical model, moving from basic research to field testing, and finally to adoption within the community. At all stages, information can flow forward as well as back to allow the most sustainable holistic solutions to be achieved.

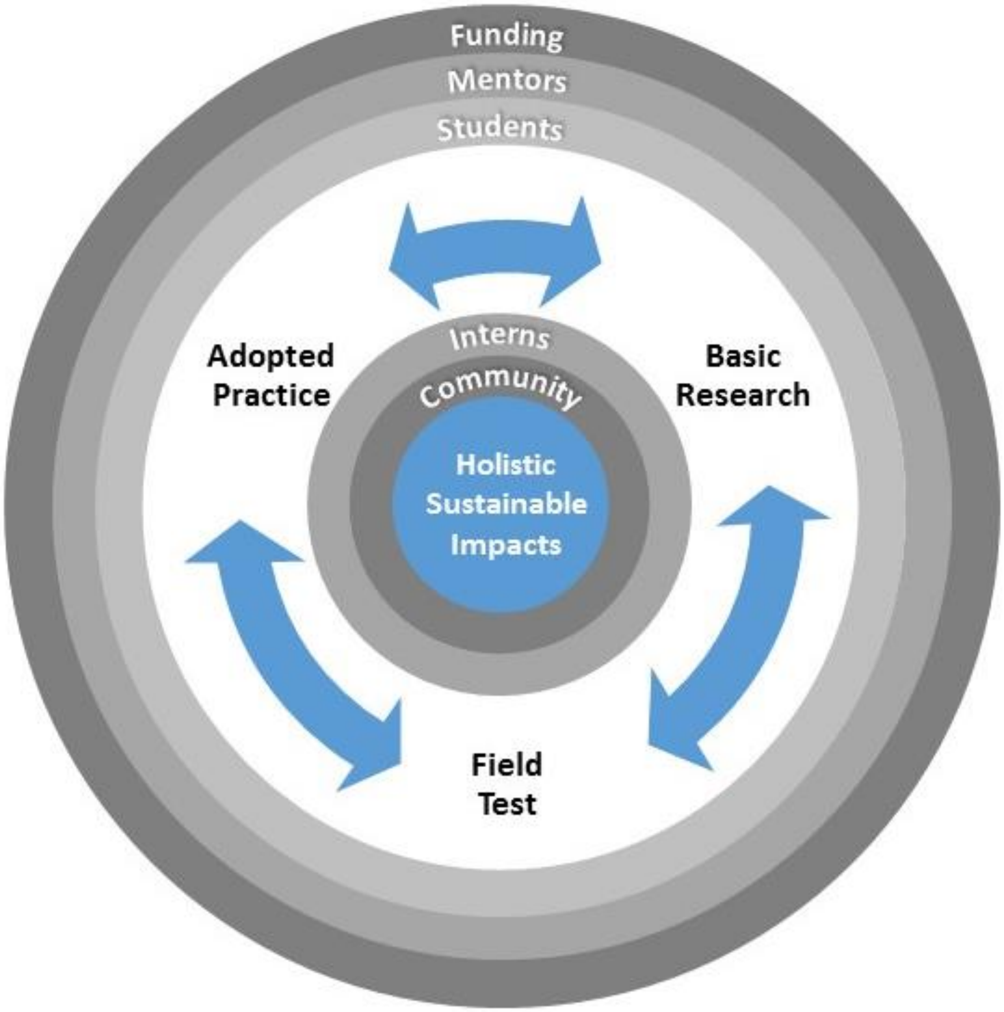


Figure 3: Translational Research Model for Engineering

Differences between Translational Research and Problem-based Learning / Service-Learning

Problem-based learning (PBL), as with translational research, originated in the medical and health disciplines and is still used extensively.[18] Prince and Felder[18] define PBL as follows, "students—usually working in teams—are confronted with an ill-structured open-ended real-world problem to solve, and take the lead in defining the problem precisely, figuring out what they know and what they need to determine, and how to proceed to determine it. They formulate and evaluate alternative solutions, select the best one and make a case for it, and evaluate lessons learned." Research[17] has shown that problem-based learning enhances: the student's ability to apply concepts learned in one context to another, collaborative work, retention, and design thinking. There is evidence that problem-based learning at the freshman level increases retention of women and under-represented minorities by building learning communities early in their college experience.[17] In reviews of inductive teaching methods[18] and active learning approaches,[19] approaches such as problem-based learning, project-based learning, case studies and just-in-time-teaching are conclusively better than the traditional deductive methods in terms of problem solving skills development and self-regulated learning strategies, as well as building teaming skills. However, while the problems are based in real-world contexts, there may be no actual connection to a real community, and teams may not be comprised of multiple disciplines – thus limiting the perspective of the actual problems.

Service-Learning (SL) courses, based on constructivist theory, have been shown to better prepare students to meet the challenges they will face in the global economy. Service-learning combines service to a community with academic curriculum; students apply their discipline-specific knowledge to community problems, thus engaging in problem-based learning (PBL) while providing needed services to underserved populations.[20] In service-learning courses, students have an opportunity to solve an ill-defined real-world problems with teams of students, often across multiple disciplines, which helps to broaden their "lateral" or non-technical skillsets, better equipping them for the workplace. The programmatic benefits of service-learning include: enhancement of classroom learning,[21] increased student retention,[22] and increased participation of under-represented populations.[23] As well, there are numerous benefits for student learning outcomes including improvements in: self-esteem, leadership and team-work skills, communications, and acceptance of cultural diversity, academic performance, student satisfaction and attitude toward learning.[24]

While the translational research model for engineering essentially encompasses all of the components of both problem-based learning and service-learning, it has additional components that set it apart:

- Implementation of new discoveries – At the core of translational research is the transfer of new knowledge from academic researchers to the community of practice. New discoveries are essential to making progress toward development of sustainable solutions for the complex problems our world is facing. While new discoveries may arise during service-learning, it is not a critical tenet as it is for translational research. Many existing solutions to the problems faced by developing countries require significant resources (financial, natural, and technical) and result in significant carbon footprints - neither of these traits are desirable. New solutions that have low resource requirements and net zero or even positive energy production are key to a sustainable future.
- Internships – Probably the most important aspect of the translational research model are the interns that integrate into the community. They are the heart and soul of the translational research model providing the literal connection between the research teams and community partners. They form a consistent source of support, making sure that the projects are implemented according to plan and redirecting information flows as conditions in the field change. Not all students involved in translational research will become interns, but their respective roles in the translational research process will be served by the interns. By having interns in the community, it provides an opportunity for students to understand both the technical side of the project and to become fully immersed in the implications. This level of connection enhances the project outcomes and greatly improves communication with the community.
- Inclusion of graduate students – Several existing service-learning programs include vertical integration of students as a key element. However, for most programs vertical integration of students stops at the senior undergraduate level. The translational research model is strengthened by the introduction of graduate students. The graduate students are typically ingrained in the basic research stage of the process. Graduate students are

provided opportunities to mentor and guide undergraduate students in the research and technical aspects of projects, benefiting the undergraduate students' technical learning as well as the graduate students' ability to synthesize and communicate. By having graduate students in the program, the efforts of the translational research are also more likely to be disseminated into the broader academic community in the form of journal papers and conference presentations.

- Long-term connection with partner community – Most problem-based learning occurs in a single semester, and service-learning may span multiple semesters, but the translational research model works best when the projects can be monitored and evaluated for extended periods. The long-term connection to a community exhibiting numerous societal grand challenges not only allows students to engage in meaningful projects during their tenure with the program, but to also have the opportunity to see the broader impact of the cumulative efforts of past student efforts on the community. This is a perfect scenario for understanding the long-term relationship between technology and society. The program supports this connection with enrollment of students in one-credit hour course over multiple semesters – essentially projects are passed between cohorts as new people are joining established teams each semester.
- Community mentoring and education – The students are actively engaged in mentoring and educating local community members to promote adoption of practice ready solutions. By distilling their understanding of technical topics to accurately convey information to community partners and peers, the students are overcoming language barriers, developing professional communication skills, critical thinking skills and also improving their own technical abilities.

Translational Research Model Example Application

The following example provides some highlights of an application of the translational research model. The application involves USAID-funded research on anaerobic biodigesters and a sanitation problem in the host community of Cange, Haiti. The model was integrated into an existing multi-semester undergraduate research course. The course is student-directed, and the students are organized and operate as a corporate enterprise. Through the course, students engage in translational research to solve meaningful, real-world problems and create holistic sustainable impacts in Haiti. Since its inception, the mission of the program has been to work with local communities in the Central Plateau of Haiti to develop sustainable solutions that improve their quality of life.

Starting with an ill-defined problem identified in conjunction with the Haitian community, students collaborate over multiple semesters with the university research community and with the Haitians to research, design, and test holistic and sustainable solutions to problems. A number of private industry, public agency, and NGO partners support the program as subject matter experts as well as funding agents. Throughout the field test phase interns work closely with the local Haitians to ensure that all steps of the implementation and training meet the expectations and context of the community. Finally, the team works together to launch successful projects into local practices, or returns to the research team if new solutions are necessary.

The following example project provides a basic understanding of the model application going from basic research to adopted practice. The project addressed a strong need in the community for a sanitation system to support local health clinic operations as well as the community at large.

Background

In developed countries around the world, treatment of human waste is so ingrained in society that it mostly goes unnoticed to the average citizen. Unlike power lines and roads, this vital part of our own infrastructure is not visible on a daily commute to work or school. The benefits from wastewater treatment have been felt for generations and the gift it gives to each individual is not glorified. However, this network of underground plumbing, waste disposal, and treatment has given the United States and other industrialized nations decades more life expectancy and preserved the natural resources that make these societies a beautiful place to live.

Other regions of the world have not been so fortunate. Due to war, poverty, and natural disaster, many people still fight the diseases brought about from limited, or a complete lack of, waste treatment. Many pathogens, such as dysentery and cholera, are transmitted by human or animal waste. Many rivers and ponds are drained of fish when the oxygen demand from this waste leaves these bodies of water fit only for algae and other microorganisms. For the benefit of fellow men and women, sharing our knowledge and finding a way for them to effectively treat their waste cannot be understated.

Problem Identification

After multiple trips to the Central Plateau of Haiti, students in the program had many questions about the water sources, water storage, and sanitation practices of the local community. It was clear from conversations with doctors in the local clinic that cholera was rampant, and numerous people had died from the disease. In response, a research team made up of students from civil engineering, public health, computing, geology, and environmental engineering developed a water and sanitation survey and worked with the university Institutional Review Board, the local community, and the interns to collect data on local practices. Because no street addresses are available in Haiti, the students developed a geographic information system platform to store the location of the houses so that water source boundaries could be identified. The results of the survey indicated that the overwhelming majority of the Haitian community members did not have access to sanitation facilities. Most residents used a private spot of ground as their toilet. Though a natural choice, the practice doesn't effectively remove the pathogens from the human environment. Given that the residences are located mostly above the water sources used for drinking, the waste and diseases are carried by precipitation to groundwater or runoff to streams that feed into the drinking water supply. This condition creates a vicious cycle leading to infection of additional people and a repeat of the disease cycle.

Initial Research for Solutions

In search of sustainable solutions for treating the waste problem, a research team made up of students from ecology, civil engineering, and biosystems engineering came across a number of research projects on anaerobic digestion. The team found small biodigester systems implemented in villages with populations ranging from 750-2,000 in impoverished countries like Costa Rica, Mexico, Honduras, and other small South American countries. However, most of these systems were run off of agricultural waste such as pig, bovine, and chicken waste with the intent of energy production. Only a few (2-3) resources were identified for systems that run of off human waste and these systems have been used in larger scale in an urban environment. The team decided that they would either need to adapt the small, rural agricultural biodigester to run off smaller amounts of less nutrient-filled human waste or adapt the large urban biodigesters to a smaller scale along with simpler fabrication. The research team established a connection with a research team at University of Maryland that had received USAID funding to study small scale implementation for small rural farming operations. The researchers welcomed an implementation and evaluation in the host community of Cange, and initial plans were sketched out for the collaboration.

<u>The Sustainable Living Solution Project Development</u>

An anaerobic digester is a biological tool that will remove pathogens from the waste stream. By centralizing the community waste stream and manipulating the flow regime, an anaerobic environment can be created. Human waste pathogens are not metabolically fit to compete in these environments. Other microorganisms will colonize the system and out-compete these pathogens for nutrients and space. The wastewater enters the anaerobic environment with pathogens and nutrients. The water leaves the system with much less nutrients and a logarithmic decrease in coliforms and other disease causing organisms.

The benefits of the anaerobic digester exceed pathogen removal. The digester ecology also produces biogas. Through the metabolism of the microbial community organic matter in the waste stream is converted into methane, hydrogen, and carbon dioxide. This mixture of gas can then be piped to any gas burning stove to be used as a sustainable cooking fuel.

Current students built on the work of previous cohorts of students who had defined the problem through the survey, researched waste treatment solutions, and identified research and industrial partners. The new, larger group of students took on the task of designing an implementation. The resulting system included latrines, a biodigester system, a methane gas capture and piping system, a communal kitchen design, and a wetland growing area. A sketch of the system is found in Figure 4. For each component, a separate group was formed to conduct alternatives analysis for various implementation designs. Three separate groups, of three to six students each, were formed including the latrine group (civil engineering and environmental engineering), the communal kitchen group (mechanical engineering, civil engineering, and industrial engineering), and the biodigester group (ecology, civil engineering, and biosystems engineering). While the groups took on the research and design of the implementations in smaller teams, the project management structure of the translational research program kept the groups abreast of all interactions between teams and coordinated information flows.

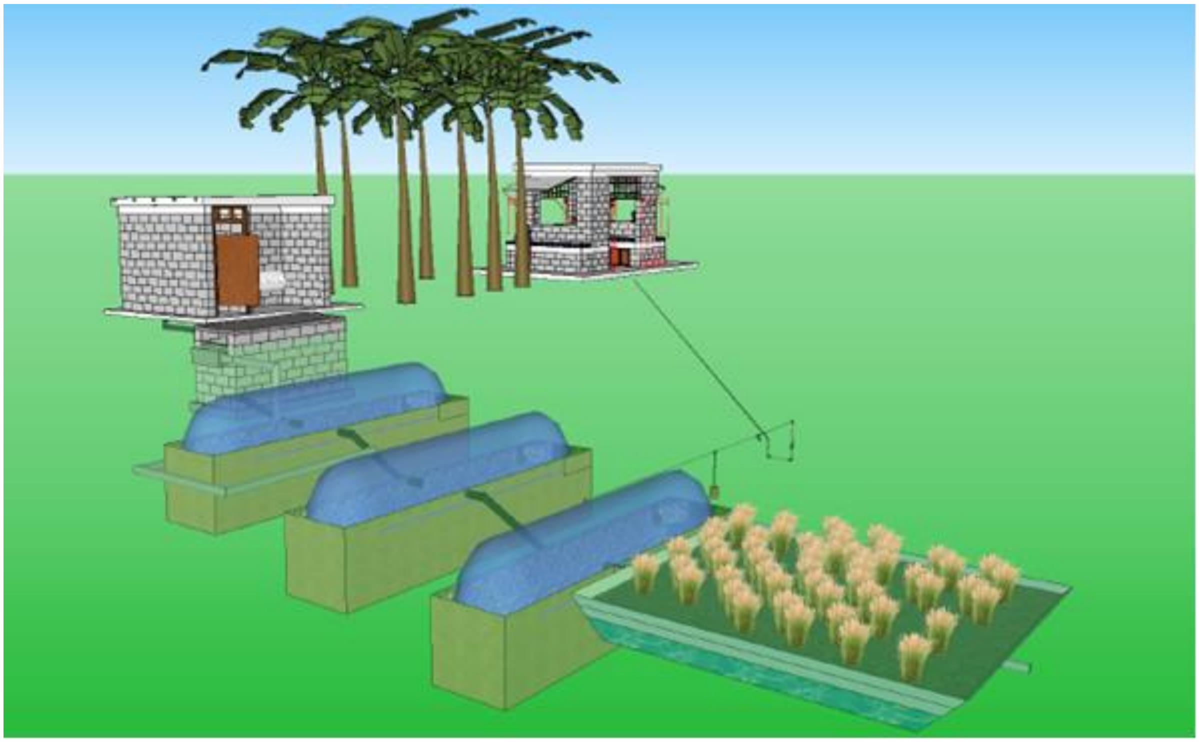


Figure 4: The Sustainable Living Solution

<u>The Interns and Community Interaction</u>

At the end of a semester, the latrine group had successfully completed the design and output evaluation for the latrines. A drawing of the overhead view of the latrine can be seen in Figure 5. The team sent 3D sketches of the design to the interns on the ground in Haiti to have the local residents assess the designs. The feedback was not positive. The locals did not like the enclosed look of the latrine building and were afraid that the odors would be encapsulated in the closed space. They requested a more open architecture format with the latrines open to the outside (with privacy doors, of course).

The information was relayed to the research team, and additional designs were developed. The revised drawing can be found in Figure 6 with 3D sketches in Figure 7. The revised latrine design consists of an open-air facility with no exterior walls. Doors will be installed for privacy at the toilets, but the urinal will remain open. Concrete masonry unit block will be used to construct the walls that will be built on a concrete slab. Four low-flush toilets will be installed, along with a two-person urinal trough, and an exterior sink.

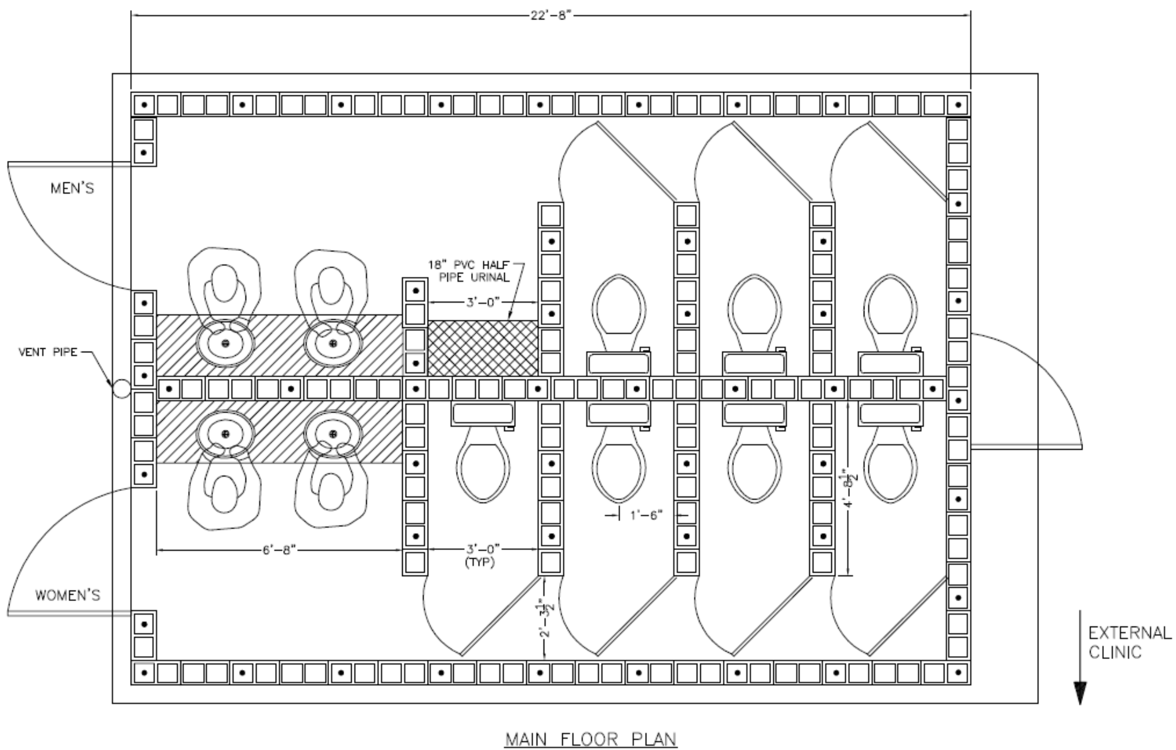


Figure 5: Overhead View of Latrine Design – Version 1

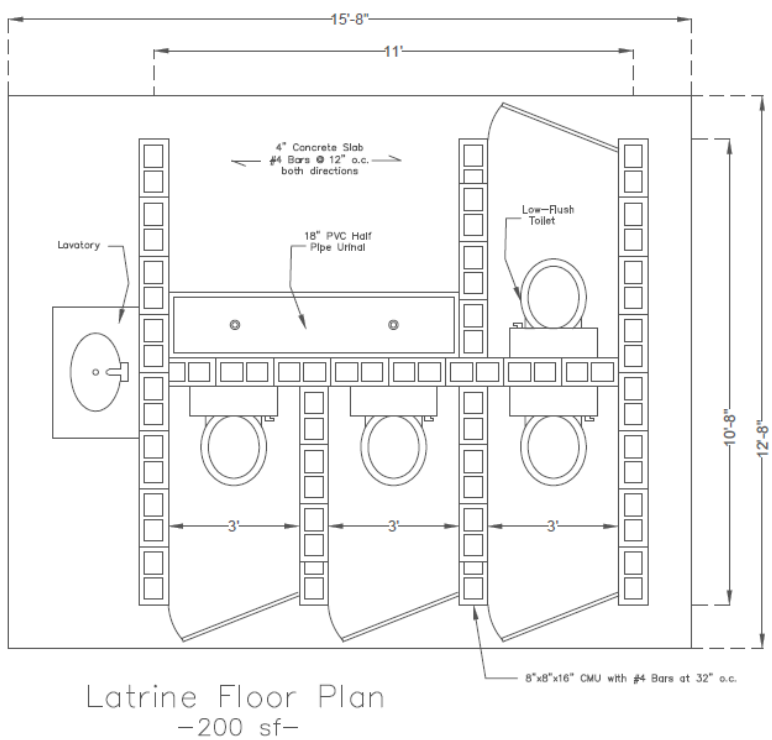
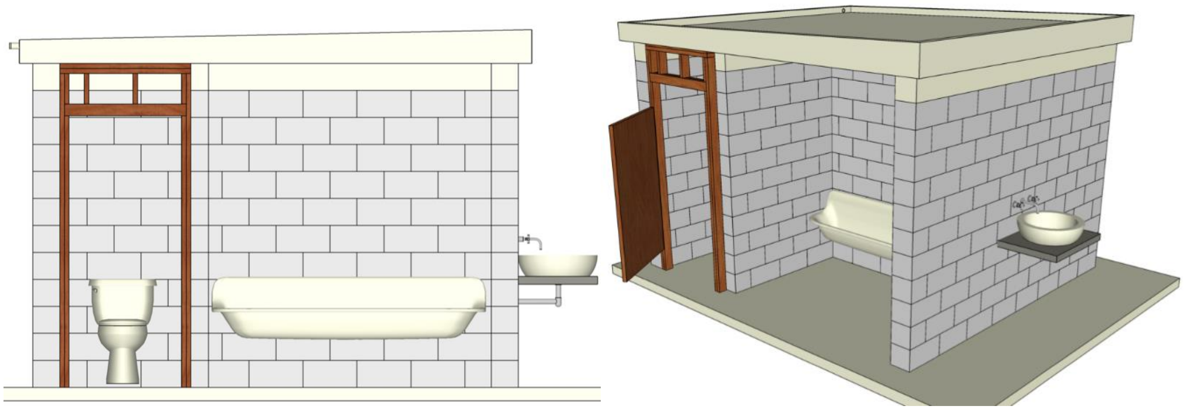


Figure 6: Overhead View of Latrine Design – Final Design

Side 1



Side 2

Figure 7: 3D Sketch of the Final Latrine Design Shared with the Local Community

Because the design of the system is complicated, the interns were having a hard time explaining all of the components of the system to the community locals and what it would look like in real life. In the local community, the interns had met a student who aspired to be an architect. He had shown them several models of homes that he had built, and they commissioned him to develop a model of the sustainable living solution (see Figure 8). The model proved to be quite useful in explaining the components of the system to the local residents as well as a tool to refine the design. Note the model includes a sloping roof with overlapping sections. This design was suggested by local builders as a means to provide additional ventilation in the structure. The overlap provides rain protection from the opening between the sloping slabs. This detail was added after the revised drawings, but prior to construction.

Figure 8: Sonson the Aspiring Architect and His Model of the Biodigester/Latrine System

Once the designs were completed, the interns worked with a local construction crew to develop materials lists for the project and planned oversight for the construction. One of the interns who was in the host country at the time recalls his practical knowledge development in the field as follows:

> "The main project I was working on was the latrine. Last semester my team came up with the design for this latrine so seeing it being built is exciting. I have spent a lot of my time trying to purchase the correct materials. The local plumber, Boss Desalon, gave me a list of materials that he would need for our design and Sam and I went to Port-au-Prince with Boss Maurcelin, the local construction foreman, to buy all the piping so we could hit the ground running…So, we had the materials ready for the group and when they arrived it was pointed out to me that the PVC pipe we had purchased was for water and not for sewage. The difference is the radius of the turns and how sewage is able to flow through it. So, on Monday I returned to Port-au-Prince. We returned with all materials and started with our plan."

The interns at the time completed the initial construction as shown in Figure 9. The next wave of interns had the opportunity to commission the biodigester. The following description of this process was taken from the intern's blog. Figures 10 and 11 accompany the blog excerpt.

> "Manure Monday **(**Warning: graphic images of biodigester food, probably not dinner time reading material.)
>
> I know I mentioned biodigesters before, but a quick refresher; anaerobic bacteria break down waste leaving the little pathogens fresh out of little pathogenic habitats, and they die. So the best way to get a biodigester's digestive system rolling is to give it a lot of bacteria rich waste, in this case, fresh cow manure. Our intrepid poop scoopers (Sam, Alan, and Colon) went to market day in Kas and collected a still warm steamy fresh bag of about 30 gallons of cow waste. Unfortunately it started raining as they were leaving Kas, right about the same time 10 or so people decided

to hitch hike and jump in the back of the pickup truck. Minus the details, probably not what they bargained for.

They returned safely and all that remained was to seed the first digester. You might ask, ‘how does one get cow pies into a biodigester?’, and you would practically have been part of our conversation. We reviewed our options, and decided that trying to flush it all down the toilets was probably not our best option, or cleanest. Instead we found among our miscellaneous biodigester supplies, a tarp-like-bag with a 4" PVC insert in the middle, which conveniently fit into the clean-out at the end of the biodigester.

The rest was simple, shovel some manure, add some water, ram it down with a broom handle. And by simple I mean alternately comical, messy, educational, humbling, comical again, and ultimately successful. The best part is, we get to do it again tomorrow! Remember kids, get your degree, otherwise you could end up doing heaven knows what.”

Figure 9: Latrine/Biodigester/Wetland Construction Phase Complete

Figure 10: Biodigester Seeding

<u>Ongoing Evaluation</u>
After the interns worked with the locals to construct and commission the latrine, biodigester, and wetland, they immediately began testing the effluent water to ensure the removal of pathogens, as well as monitoring the latrine inflows and gas production. After operating the system for some time, gas lines and scrubbing devices were added to the system to transport the methane captured in the biodigester bags to a community kitchen. The interns added gas production to their monitoring plans. Although the initial results indicated too little waste was being captured by the system, the systems were still operating as planned but with less production than expected. The interns identified an additional connection to new latrines at the local school, and now the system is operating more efficiently. Ongoing evaluations continue. The interns in the field collect data with local support and provide it to the research teams at the university for evaluation and continued research development

<u>Practice Ready Solutions</u>
After the larger system was installed, another version with smaller bags and a single latrine was installed at a local vocational school and used as a training tool. The smaller system continues to function efficiently and represents a model for small remote residential communities. Currently, several community members have indicated a desire to obtain these smaller latrine/biodigester systems for their remote villages. At least one community co-op has been established and residents have started to collect money to operate and maintain a system. In response, the translational research program has tasked a research group with developing a proposal to install

multiples of these smaller systems for testing in remote areas which still have ongoing issues with cholera outbreaks.

Key highlights of the model framework for this application:

- Funding – The original basic research was funded by USAID, implementation capital costs were funded by an NGO partner, and interns were supported through an internal university internship program.
- Mentors – Research mentors were numerous across multiple universities both in the US and abroad; faculty from multiple disciplines, ranging from public health to environmental engineering to civil engineering, supported the students at various stages in the process; practicing professionals from local industries helped review design plans and supported logistics; biodigester suppliers also worked with the students to help size the system and develop materials specifications.
- Students – Students from multiple majors over multiple semesters moved through the three phases from basic research to field testing, and finally to adoption within the community.
- Interns – At all stages, information was exchanged between the researchers, practicing professionals, and the host community. This was accomplished mostly through the interns in an effort to achieve the most sustainable holistic solution possible.
- Community – The community was included in the process from the beginning, reviewing plans, making design improvement, and ensuring that the project will meet the needs of the local community. The interns successfully worked with the research teams and local students to develop models and graphics to aid in communication of highly technical systems. The community has responded positively by establishing co-ops to continue installation of the smaller systems in more remote areas.
- Impacts – The final design has a net positive energy production, removal of pathogens from the environment, production of agriculture in the wetlands, and has had positive health benefits.

Enhanced Educational Outcomes from Translational Research

The translational research program engages students from multiple disciplines and at all stages of their undergraduate and graduate careers as they work in collaborative teams. Students work their way up the ranks in the hierarchical organization, gaining more responsibilities and leadership opportunities each semester. Over its six plus years of existence, the research course has grown from 7 students to 100 per semester, spanning 30 departments and all colleges within the university. The interdisciplinary translational research approach has encompassed the campus and offered an innovative international learning opportunity to the student body.

The impact of the program is evident in the magnitude of its student, intern, faculty, and industry participation. Since 2009, over 600 students have participated in the research and implementation of over $2 million in infrastructure and economic development projects. 16 student interns have spent at least seven months each in Haiti to train community members and to oversee field tests and implementation of practice ready solutions. Solutions include the installation of the first chlorinated municipal water system serving over 5,000 individuals in Haiti's Central Plateau, as well as a sustainable sanitation and energy production system. Subsequent smaller projects in remote villages have impacted thousands more. Well over 100 students have traveled to the Central Plateau for short-term engagements with the community. More than 20 faculty members and 30 professionals have supported the course with their expertise and mentored teams through the phases of translational research.

The impacts of the translational research program in the classroom have been related to retention, increased diversity in a STEM program (increased numbers of females, minority students, and non-STEM majors), and professional skill development. Many students have remained active in the program long after they have completed the three 1-credit hour course requirements; STEM females have been engaged at a rate that is double that of the female population of the engineering and science colleges at the university; interest and involvement from non-STEM majors has steadily increased each year; and students have excelled in communication skill development as compared to peers. One of the graduate students who has been involved with the program since his undergraduate years authored a tagline for the program that speaks volumes, "Serving the developing world; developing those who serve."

The translational research program has built an intimate and trusting relationship with its Haitian community partners. This provides a rewarding experience for all participants, regardless of whether they reside in Haiti as interns, make short trips to Haiti on breaks, or work solely on the projects from campus. Students, both domestic and abroad, regularly communicate with their professional network partners and community partners, refining needs assessments, troubleshooting problems, and gaining insight on implementations.

Not only are the students engaging with the Haitian community and students from multiple colleges and disciplines across the university, they are also developing professional relationships with the practitioners and faculty who help mentor these groups throughout the project lifecycle. These relationships are now being used to develop and support other initiatives.

All students who travel to Haiti are required to share their experiences upon their return through reflection documents, presentations, and exchanges with project groups. This step addresses a common challenge of how to bring international perspectives and experience to those students who may not travel, and prepares students for the collaborative problem solving that they can expect in their careers. In this way, students recognize the relevance of multidisciplinary training. One student commented that cross pollination was the most important student aspect; "many of the engineering students, including myself, have been so close minded in our studies that we never truly learn what makes a project thrive…Functional communication with managers, accountants, marketing, document control groups, construction, procurement, etc. are all necessary for even the smallest projects to come together."

Students in the translational research program gain more than hands-on experience in their profession; they witness poverty, sickness, and an unwavering sense of community that few had imagined before their involvement in this program. The struggles of a developing nation give these students a renewed sense of purpose. "Walking up the steps from Bas Cange made a huge impact on me. I tried to imagine not being able to go to school because I needed to walk those steps with a heavy load of water. It changed my perspective of what is difficult and what is important."

The impacts on the community have been equally extraordinary. In the remote villages surrounding Cange, Haiti, community members have begun to develop community co-ops to raise funds to aid in installation and maintenance of their own biodigester systems. In the main village of Cange, there have been no incidences of cholera since the nearly net-zero-energy chlorinated municipal water system was installed. The students have also helped a concrete block manufacturing facility change its processes to double the strength of its blocks at minimal cost. Improving building materials and training local building professionals on life-safety building codes will prevent the senseless deaths of hundreds of thousands of Haitians in the wake of another earthquake like that of 2010.

In a recent survey of student outcomes, students participating in the translational research course were asked about their favorite aspect. The following list provides an array of the actual responses received, and groups them into some common themes that align with the desired outcomes:

1. Professional Development
    - "The corporate structure of the program organization - I think overall it is very well organized"
    - "[It] allows you to grow as a leader while you are changing the world"
    - "It encourages the project and go-getter mindset"
    - "The way the class enables you to become a better public speaker"
    - "Learning things I wouldn't ordinarily in class"

2. Real World Experience
    - "Getting hands on learning"
    - "Real life expectations - The program breaks down the barrier between the classroom and the real world"
    - "Being able to work on real world situations and find solutions"
    - "The project topics are all interesting because they all rely on creating solutions to difficult problems in a foreign country that doesn't have access to many materials"
    - "Being able to bring real world solutions to other people and apply the knowledge and skills learned in the classroom to real world situations"

3. Multidisciplinary Collaborative Teamwork
    - "I like the community atmosphere that [the program] provides and the chance it gives each individual to make a real world difference"
    - "Overcoming challenges with my group"
    - "The teamwork that is built up between groups"
    - "The variety of people that are in the program"
    - "Working together towards a common goal"
    - "Meeting and learning about the different groups and projects"

4. Global Impacts
    - "The real impact it has"

- “The end goal of the program, providing assistance to those who need it most.”
- “Getting to see what we do actually make a difference. It applies my knowledge to the real world.”

Conclusion

The objective of this paper was to show how translational research can be applied in a multidisciplinary engineering education setting and to provide a framework for achieving it. As discussed, the model builds on the foundation of problem-based learning and service learning and shares their benefits. Added benefits resulting from long-term residency of interns in host communities allow research teams to be in constant communication with the community partners providing efficient bi-directional flow of information on field tests and implementations leading to more sustainable long-term solutions. The vast array of expertise needed to move projects from the lab to the field predispose the model to multidisciplinary involvement. As students discern the need for additional expertise, they organically grow the research network pulling in other students, faculty, and practicing professionals to fulfill the gaps. Finally, the model encourages students to be creative and innovate and/or seek out new research, especially discoveries that contribute to the framework of sustainable development. The translational research model found commonly in the medical field can and should be adopted to enhance multidisciplinary engineering education. Doing so will encourage faster adoption of innovative discoveries and practices, and helps to coalesce the students, academic researchers, practicing professionals, and the communities that they serve. All of these aspects lead to holistic sustainable impacts in our communities.

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