Design and Implementation of a Community-Driven Clean Water System in a Rural African Village

Vision

To empower this community to overcome challenges with basic infrastructure so they can have a safer, more sustainable, and more prosperous future, and to engage engineering students in a highly collaborative design program that in turn helps improve the lives of others.

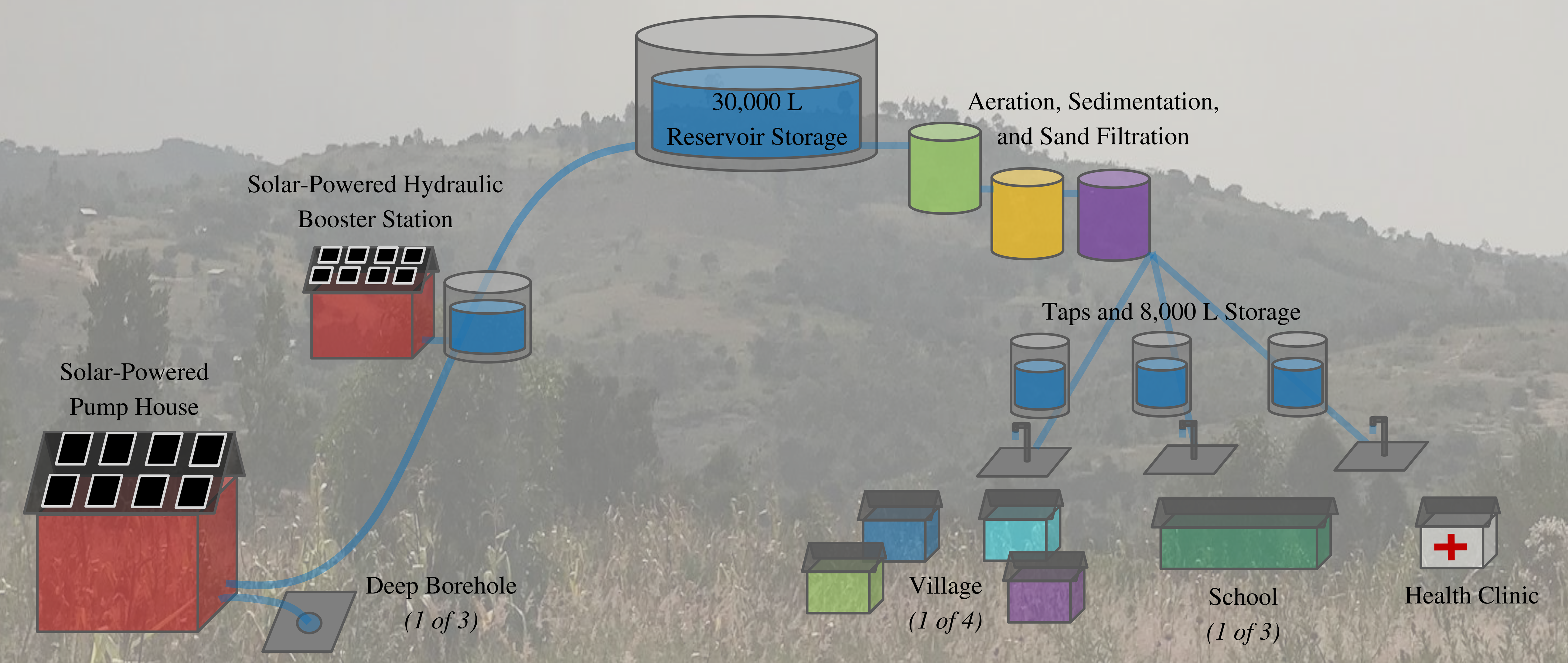
Introduction

This project aims to bring clean drinking water to a community of 3,000 in rural Africa after years of insufficient amounts of water and waterborne illness. The full project spans assessment, water source development, physical water treatment, solar-powered distribution, and sustainable storage. Undergraduate engineering students have been tasked with the design and implementation of each component with mentorship from several university faculty mentors and professional engineers.

Public Welfare

Access to sufficient quantities of potable water is a basic human need that, for many years, this community has not had access to. With the introduction of this water system, tap stands with treated water will be located at key points throughout the village, meaning the community will have access to higher quality water while expending less time and effort to retrieve it. Additionally, the water system will provide potable water directly to the local schools and health clinic, so supplying children and the sick with water will become a simpler endeavor.

The Project



Relevant Skills

Soft skills

- Effective teamwork
- Intercultural collaboration
- Project management
- Technical writing
- Technical presentations
- Design code integration

Technical Skills

- Computer-aided design
- Hydraulic modeling
- Geographic information systems
- Structural design
- Land surveying
- Construction supervision

Collaborative Efforts

- Direct design collaboration of students with licensed professional engineers and university faculty
- Distinct construction and implementation collaboration with local undergraduate engineering students
- Operational collaboration with the local and in-country divisions of the supporting NGO
- Cross-cultural collaboration with in-country contractor, hydrogeologist/driller, and suppliers
- Interdisciplinary collaboration with doctors serving community with medical missions

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Project description

A collaborative project between a university Student Engineering Group, a Professional Engineering Group, a Non-governmental Organization (NGO), and a rural African village was conducted to increase the overall production, quality, and accessibility of potable water to the village, as per the community's evaluation of their most pressing needs. The partner community of this project consists of 4 sub-villages, and totals approximately 3,000 individuals. The community suffered from a lack of sufficient potable water, particularly in the dry seasons that occur twice per year. The community and their partner, an NGO medical mission group, stated that the frequency of waterborne illnesses and the occurrence of longer, more severe dry seasons in recent years, spurred them to reach out to the Professional and Student Engineering Groups for assistance. Therefore, the groups formed a partnership with the goal of increasing the community's access to year-round potable water to increase the community's overall quality of life.

The first trip to the partner community by the Engineering Groups was one week long, with two professional engineers and two student engineers traveling with three members of the NGO. A local hydrogeologist was contracted in this time to help decide the best options for the community to have access to water year-round. The primary intentions of the trip were to assess the community's goals for the partnership and ensure community investment and agreement, collect data on the community's current water quality and access to water sources, and decide on the solution that would best fit the community's current needs and long-term goals.

In the months following the assessment trip, the student engineers worked with several members of the Professional Engineering Group to decide which potential solutions would make the most sense for the community. The main water source solutions that were considered included using the currently available surface water sources, rainwater catchment, or deep boreholes. Possible water treatment alternatives included sunlight concentration, a chlorine drip system, a simple filtration column, boiling, and a three-stage system consisting of aeration, sedimentation, and slow sand filtration. The consideration criteria included sustainability, cost, maintenance requirements, equipment reliability, expansion capability, and community approval.

It was determined that the most promising solution to increase the quantity of water available to the community would be deep boreholes, as they could provide water that would require less treatment than the available surface water sources, and would not run dry once the rainy season ended. The community also had two boreholes that had been drilled previously, but tested very high in iron and were abandoned due to poor taste and reports of the water turning black several hours after being collected. From this information, it was anticipated that any deep boreholes in the area would contain significant amounts of iron and manganese. Therefore, it was proposed that the student engineers would work on plans for a pilot treatment plant that could filter out iron and manganese using aeration, sedimentation, and slow sand filtration in series. This design was based on the professional engineers' past experiences with this type of contamination. The community was satisfied with the solution proposed by the engineers, and the student engineers began drafting plans for the first implementation trip. Several iterations of the pilot treatment plant design was reviewed and approved by several members of the

Professional Engineering group before being approved by several professional engineering reviewers.

The next trip, occurring nine months after the first, was a two-week implementation trip during which two deep boreholes were drilled, one of the old, abandoned boreholes was rehabilitated, and the pilot treatment plant was constructed to test the efficacy of the treatment plant design. The student engineers were involved with overseeing pilot plant construction and editing the plant design based on available resources and the immediate circumstances. They also conducted surveying to prepare for the anticipated future implementation of distribution piping and kept tabs on the contracted well-drilling team's progress. The boreholes all produced upwards of 3,000 L/hr, and the well with maximum production could sustain 6,000 L/hr for an 8-hour pumping day. The pilot plant has been successful at removing over 85% of the iron from the boreholes' water, consistently bringing the iron levels from over 5 ppm to below 0.6 ppm. The manganese expected did not appear to be present, meaning the treatment plant will primarily be used to remove iron and bring turbidity to below 10 NTU.

Currently, the student engineers are working in teams of three to six to design the structures, full-scale treatment plant, solar power system, and distribution piping of the system. The students are designing solar-powered pumping stations that will be placed at each borehole as well as at an intermediate pumping station. The solar panels will affixed to the pump house roofs to provide adequate support for the arrays while keeping them out of the reach of animals, shade, and children. There will also be storage tanks located at each of the three boreholes, the booster pumping station, the treatment plant, and several taps in the village. The treatment plant is being scaled up and improved while retaining its modular design for anticipated expansion. Hydraulic modeling software is being used to model the full system of piping between each component of the system.

Each team is also responsible for their associated technical drawings and sourcing the necessary equipment from vendors in Africa, to ensure that the community can purchase replacement parts nearby. After each team has their designs and drawings approved by a professional engineer, the designs will be integrated into the full project design, which is on track to be completed fewer than seven months after the first implementation trip.

Collaboration of faculty, students, and licensed professional engineers

The design and implementation of the water collection, distribution, and filtration system would not have been possible without thorough collaboration between students, faculty, and professional engineers. The students managing the project worked closely with professional engineers from several different backgrounds, in addition to faculty mentors from the university. The Student Engineering Group worked primarily with five mentors from the Professional Engineering Group, three of whom traveled with members of the Student Engineering Group to provide onsite engineering expertise and oversight.

Professional engineers met with students from the Student Engineering Group on a weekly basis to guide the design process and provide feedback and comments on drawings and reports. For each implementation, the final system design must be approved by a professional engineer, who certifies that the design, specifications, and calculations are of sufficient quality for professional approval. The continuous feedback from the Professional Engineering Group mentors ensured that the students were producing high-quality work that would pass inspection by professional engineering reviewers when each project report was submitted.

From their collaboration with professional engineers and faculty mentors, students learned how to interact in a professional environment and gained technical skills from attendance at technical conferences led by professional engineers. Additionally, multiple professional engineers and faculty mentors held technical workshops teaching the fundamentals of EPANET, AutoCAD, and solar-powered systems, which allowed students from any discipline to learn the skills needed to design and model a water collection, distribution, and filtration system. The technical skills gained through these workshops are not explicitly taught within the classroom, which makes the experiences of the students from the Student Engineering Group at these workshops unique and irreplaceable. Faculty mentors also led workshops focusing on skills such as project management and successful communication, and have met with some of the Student Engineering Group leaders to discuss these and related topics in-depth.

In addition to the involvement of professional engineers during the design process, the Student Engineering Group worked closely with engineering students of the partnered community in Africa. This allowed the Engineering Group students to benefit from the involvement of both professional engineers and fellow engineering students from vastly different backgrounds. The understanding of the local engineering students of the system design was an important aspect of ensuring the sustainability of the water collection, distribution, and filtration system over time.

While in the partner community, members of the Engineering Group also had the opportunity to work with a variety of other professionals, including a hydrogeologist, construction manager, and members of the community with agricultural and plumbing certifications. The plethora of different skills and accreditations that the collaborating professionals brought to the project were vital to the quality of the finished design as well as the educational experience of the students involved.

Protection of health, safety, and/or welfare of the public

The primary motivation for this project was to implement a sustainable, community-driven solution to the community's need for year-round access to potable water. In the assessment of the community issues, it was clear to the Engineering Groups that water quality and availability had a significant impact on the health of the community. Through the design of a water collection, distribution, and filtration system which increases access to clean drinking water, the welfare of the community is expected to increase dramatically.

Boreholes became an integral part of the solution due to the elevated water quality in comparison to surface waters. The microbial agents found in most surface water sources in the area were considered a significant health concern and factored heavily in the solutions analysis phase of design. The water obtained from the drilled boreholes still had high levels of iron, but requires simpler treatment solutions than the combination of high iron, high turbidity, and presence of microbial contaminants of the surface waters. In order to address the metal content of the water from the boreholes, the Student Engineering Group, in collaboration with professional engineering and faculty mentors, designed a modular physical treatment plant consisting of aeration, sedimentation, and slow sand filtration.

The development of the water filtration and distribution system will greatly improve the quality of water available to the community as a whole, and also the health clinic of the community. The health clinic in the community has an urgent need for sufficient quantities of high quality water. The development of the water treatment system, in conjunction with distribution straight to the clinic, will serve to fill this need for both the health center. With access to this water, the health center can better treat its patients and work with them to provide adequate health care options. These abilities provide the community with opportunities to tackle the health problems they are facing on their own by reducing a primary inhibitor of better medicine.

The solution to be pursued by the student engineering group was developed in collaboration with community leaders so that the work of the student engineering group would be accepted and impactful for the community. The local economy of the partnered community was protected by hiring local labor to execute the final design. This promotes community engagement and provided an opportunity for community education about the project to ensure sustainability. The process of evaluating the issues of the partnered community and then working to address them was a valuable experience for the student engineers on the impact of humanitarian engineering initiatives. The final result was evaluated from a professional engineering and community perspective. This approach ensured that the system was functional, helpful, and used by the community, which encapsulates the overall objective of the student engineers.

Working with an African community challenged the student engineering group to develop their world view and consider how engineering can help solve problems faced by communities all over the world. Students were faced with the challenge of addressing the substantial issues of water scarcity and quality with only the resources available to the partnered community. Students were pushed to develop self-reliance and responsibility for the successful completion of their portion of the project and communication with the community and collaborating professional engineers. The Student Engineering Group learned to cooperate with one another, their mentors, and the community leaders to design and implement a successful water system through numerous design iterations.

Multidiscipline and/or allied profession participation

Throughout the duration of this project, a wide variety of engineering disciplines have been incorporated and applied, the primary ones including chemical, civil, electrical, and structural engineering. Non-engineering skills were also needed. The specific skills used from these disciplines include, but are not limited to, budgeting, construction and implementation scheduling, design drafting, fundraising, international communication, performing hydraulic calculations, solar power planning, structural analysis, surveying, and team and project management.

The student engineers themselves are studying a variety of disciplines, including electrical, mechanical, chemical, biomedical, and computer engineering, as well as computer science. Throughout the course of this project, though, members of the Student Engineering Group have learned skills that go well beyond what they have learned in their classes, and beyond even what they would learn in their professional career.

Although some of the students working on this project have attended regional workshops on humanitarian engineering-related topics, students generally lack the kind of in-depth, real-world experience needed to undertake such a large-scale project. So, the planning and implementation phases of this project have employed the knowledge several professionals with years of experience working on similar water projects or in other beneficial fields, including seven engineers, two doctors, and four engineering project reviewers. The engineers involved have credible degrees and work backgrounds in chemical, civil, electrical, and structural engineering. Of these engineers, some have sub-disciplines in controls systems, geotechnical engineering, potable water and waste management, and surveying. While some of these professionals have contributed to this project by directly assisting with the design and planning during weekly meetings or by going on trips to the village, others have contributed by assisting with the large amount of fundraising required, or by reviewing the project to ensure that the decisions and calculations being made are rational and justified.

Aside from the professional mentors that have regularly aided this group with the project, several out-of-country contacts have also been helpful at various times. Two locals of the partner community of this project have served as in-country contacts, providing insight on realistic community needs and resources. Several community members have taken an interest in the project, including members with plumbing and agriculture certifications and two university students studying civil engineering. Connections with three African solar companies have helped with the detailed planning and design of a solar-powered borehole system. Although only one of these three companies is being used for purchasing and installation purposes, three were contacted to ensure that items such as panel pricing and mounting style were reasonably decided based on available resources. A hydrogeologist in Africa has assisted this group by performing a hydrogeological survey of the village; this allowed him to provide an educated recommendation for the location of the boreholes, which he was then contracted to drill and develop.

All of these disciplines were helpful in creating this large-scale, multifaceted design, to the extent that without some of them, the project would not have been possible. Therefore, a multidisciplinary team was not only helpful, but vital to the project's success thus far.

Knowledge or skills gained

Students from the Student Engineering Group gained invaluable skills from this project. They learned the benefits of working with professional engineering mentors, faculty mentors, students of different disciplines, and community members of different backgrounds. These skills allowed the students to enhance their knowledge relating to working on an engineering project with an international community partner.

The students learned to explore concepts with, teach skills to, and learn from local engineering students in the partner community, which included overcoming some language and cultural barriers. This collaborative work with the community's students and other members, who possessed different abilities and ideas from themselves, led to the students' ability to better understand their own skills and limitations, and to assist in creating a community-driven, sustainable project. This partnership allows for continuous learning opportunities that can increase the students' intercultural understanding and collaboration.

Students also learned to search for sustainable solutions in resourceful ways. The university students learned to hone their innovative skills when thinking of solutions that would be viable for the community in the long-term. For example, with limited resources, buying supplies requiring specialized equipment may not be an option, so instead students learned optimization processes to maximize their design with the materials available locally. They then relayed this information to the community leaders to assess the community's agreement with and investment in the proposed solution. A project of this type cannot be sustainable and impactful in the long term without the on-going support and approval of the community, as once the partnership between the Engineering Groups and the community ends, the community will be responsible for all future upkeep of the system. Overall, students learned how to adapt to changes and utilize community resources to facilitate a sustainable solution.

The engineering students also learned about health initiatives and waterborne illnesses common in a rural African community. From their discussions with workers at the local health clinic and other community members, the students have a better idea of the health concerns facing many African communities, particularly issues that arise from poor access to water. This deepened the students' understanding of how much this project stands to impact in the lives of those living in the partner community.

Furthermore, many skills gained from working on this project could directly translate into the students' professional careers. The students learned how to use surveying equipment to determine elevation differentials for digital models used in hydraulic design programs. Using tools such as EPANET and AutoCAD under the mentorship of professionals expands their knowledge beyond what they might have learned in a class. Additionally, the students worked with the professional engineers on a regular basis to learn the proper procedure and methods for a large-scale project. The knowledge and connections the students gained from working with professional mentors allow for them to improve their skills in working and communicating in a professional environment. The Professional Engineering Group mentors worked tirelessly with the students to help them understand proper design methods, technology, and thought processes to find the most economical solutions to the problems they were facing. Understanding the design process and the other skills the mentors passed on will help the students become leading candidates in their chosen industry.

Students learned leadership skills by holding positions within the Student Engineering Group and from their experiences with their mentors, peers, and members of the partner community. Students had the opportunity to learn about team management and efficiency from a certified project manager. They were taught how to handle a large organization of students that works with people from many different disciplines and how to bridge different viewpoints and ideas to develop an inclusive solution. Additionally, several students on the project learned how to construct and follow a budget, and schedule construction tasks in tandem with other project tasks such as surveying, water data collection, and meetings with community members. The project also involved working closely with the community leaders while following a partnership contract detailing each group's responsibilities. All of this contributed to the students' knowledge of important aspects of project management and collaboration both within teams and between teams and communities. This has allowed for them to gain an understanding of the importance of professional communication and solid agreement between all parties.

Overall, the project has taught the university students that they have the ability to work closely with communities and each other to facilitate collaborative and sustainable solutions to a pressing problem, and it has brought them the ability to extrapolate that which they've learned to many aspects of their life. The knowledge with which their mentors and partner community contacts endowed them will enrich the students' professional journeys for years to come, both in technical aspects and in soft skills. The students had to learn how to work as a part of a team of professionals, peers, and international community members, and what they have gained from these interactions are some of the most valuable skills and knowledge they will ever have.

Design and Implementation of a Community-Driven Water System in a Rural African Village

This project seeks to provide year-round potable water to a rural African community of around 3,000. The project is part of a partnership between the community, a Non-governmental Organization (NGO) medical mission group, a Professional Engineering Group, and a Student Engineering Group. The project's assessment, source development, and small-scale pilot treatment phases have been completed, and the full-scale design phase is currently underway. The full design includes solar-powered distribution to a hilltop storage facility; gravity-fed distribution through a physical treatment plant and then to key points in the community such as the health clinic, schools, and sub-village centers; and sustainable storage throughout.

A project of this type requires collaboration between the Student Engineering Group and their faculty mentors, members of the Professional Engineering Group, members of the NGO, a local hydrogeologist in Africa, and the community leaders, university students, a construction manager, and other members of the partner community. These groups and individuals working together has already resulted in improved water availability for community members located at and around the local secondary school, and with the full design, the entire community will be provided with the same.

The improved water quantity and quality that this design seeks to provide will positively affect the welfare of the community by reducing water-borne illness, dehydration, and other health issues related to lack of water and low quality water. The clean water will particularly benefit the local health clinic, which will help the village health workers provide better care to community members.

People from a variety of backgrounds have been key in bringing the project to this point. Some of the vital disciplines involved include civil, electrical, chemical, and structural engineering, as well as hydrogeology, construction, and plumbing. A variety of project management skills are also instrumental to the continued success of the project. Because many aspects of the design involve multiple disciplines, those working on the project become familiar with how to work closely with team members from different backgrounds.

Due to how interrelated each discipline is in the design, student engineers working on this project have absorbed knowledge and skills associated with each one of the aforementioned disciplines. This means they can now use their own knowledge of these topics to further this project, in addition to consulting the professionals from each background.

Such a large-scale, multifaceted project allows members of the Student Engineering Group many opportunities: to learn about intercultural and interdisciplinary collaboration, to find solutions to problems facing a community very different from their own, to work with people from a variety of technical and nontechnical fields, and to learn professional, technical, and soft skills that are not often taught in their engineering curriculum. All of these opportunities provide life experiences that will benefit the student engineers throughout their careers.