Project Haiti 2012: Providing an Experiential Learning Experience Through the Design and Delivery of a Water Purifier in Haiti

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Abstract – In this paper, we share our experiences and lessons learned from Project Haiti 2012, a project to design and install a water purification system serving 20,000 people per day in the largest tent city in Haiti. Project Haiti 2012 was the third and largest system we have built for Haitians and represents a huge success for all participants and stakeholders. This paper discusses the unique experiential learning opportunity involved in the design and delivery of the water purifier in a foreign developing country. Multiple positive educational, social, and economic outcomes were achieved including students applying knowledge gained from coursework towards a greater cause, faculty gaining experience in leading an overseas student trip, engaging Haitians to be less dependent on foreign aid, and relieving water crisis in Haiti. We hope that this paper inspires others to pursue similar experiential learning experiences and develop a repeatable engineering education model for international community improvement projects.

Keywords: Experiential Learning, Water Purification, Humanitarian Development, Engineering Education

INTRODUCTION

The earthquake that destroyed much of Port-au-Prince, Haiti in January 2010 was a rallying point for Embry-Riddle engineering students to help in a hands-on, tangible way. The desperate need for basic necessities like food, water, and shelter motivated the students to respond with a strong desire to help. The student chapter of the American Society of Mechanical Engineers (ASME) promoted the effort and raised funds to build the Project Haiti 2010 water purifier. This unit was based on an earlier Civil Engineering department's senior design project and provided 1 gallon per minute (gpm) of clean water. One student and one faculty from Embry-Riddle joined a larger group's travel for the installation. The following year, Project Haiti 2011, eight students from the Clean Energy Club and faculty designed and installed a purifier system to deliver 4 gpm powered entirely from the sun [Tang, 9]. During the summer of 2012, a team of thirteen installed the Project Haiti purifier delivering 20 gpm in Onaville, one of Haiti's largest tent cities, which has a population of roughly 100,000 Haitians.

Paper Organization

This paper describes, from the students' point of view, Project Haiti 2012's customer needs, design goals, and the resulting system. It also describes the in-field installation and training for local operation and maintenance. It also

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summarizes pedagogical effectiveness based on Kolb's experiential learning theory and success factors, followed by the conclusion and future plans.

PROJECT DESCRIPTION

Background

Project Haiti 2012 began in May 2012 when we received a request of a water purifier from our partner in Haiti: Nehemiah Vision Ministries (MVM), a nonprofit organization focused on transforming the lives of Haitians. We were asked to design and install a water purification system in the largest tent city which had a population of 100,000 people. All of these people, displaced after the earthquake in 2010, live in the foothills outside of Port-au-Prince and rely on NGOs to deliver water. NVM decided to dig a water well and install a water purifier for the people when another NGO, which had previously supplied the water to the area, stopped sending in water trucks for one reason or another. Having only installed systems delivering water no larger than 1200 gallons a day, we jumped on the opportunity to provide approximately 20,000 gallons water every day. We saw this as not only a rewarding experience, but also a major undertaking in engineering, communications, and logistics. We will describe Project Haiti 2012 from the challenging customer needs and our innovative design to the installation and operation.

Customer Needs and Design Challenges

Since the water purification system will be used to serve a large population of 100,000 people who has limited education, the system should be easily operated and need minimum maintenance. The water purification systems we have designed had low flow rate and always consisted of multiple stages that required replacements at least once a year. For such a large system, we did not see these designs to be realistic and sustainable. We decided to design a high flow rate water purification system with components that are backflushable and will last years before replacements are needed.

We also wanted to design a system that was rugged and could be run and maintained by anyone. Since the system was going to a third world country, the end user usually has limited education. Therefore, the system should be easily operated by following a pictorial user guide on a daily basis.

Although these requirements imposed technical challenges on us, the biggest challenge was to raise the necessary funds. We were able to raise approximately $40,000 for hardware and travel support, enough to build a system to serve 20,000 people per day. As a critical installation partner, NVM was responsible for drilling a well as the water source for the water purifier and providing installation and operation equipment such as a fork truck and diesel generator, but we still needed a large amount of funds to build and install the system and support the travel to Haiti for the team of 13 people.

Purifier Design and Testing

The primary technical design goal for the completed installation is achieving 20gpm maximum flow rate. The well pump, the forward and backflush pumps, and filter system are all designed to achieve the target flow rate. The system must be ruggedized and maintainable in-country. This drove the need for analog controls using time-delay relays. The piping system is organized in a way that is clearly visible and traceable for local operation and maintenance. Finally, to avoid the need for expensive replacement filter cartridges, the main filtration components are backflushable. Being backflushable means clean water is pumped in reverse removing all collected debris. This effectively removes the need for replacement cartridges and allows the filters to be cleaned in place.

The main filtration mechanism is a cascade of three different filters. First, well water enters a Disc Filter which gets rid of large debris and sediment down to 50 micron [Miller-Leaman, 5]. As the non-potable water enters the filter housing, a high velocity centrifugal action causes the sediments to spiral way from the disc cartridge to the base of the filter. Water passes from the outside of the disc to the inside and the grooves molded into the surface of the discs. These plastic discs can be removed for manual cleaning then reassembled for reuse.

Next, two 12gpm ultra-filtration (UF) membranes are used in parallel to achieve the 20gpm requirement. This stage eliminates water-borne pathogens larger than 0.1 micron using a size exclusion mechanism. The filter removes all bacteria and some virus. Each membrane is approximately 6 ft. tall with a surface of area of 460ft^2. Such large surface area allows low transmembrane pressure even at their maximum 12gpm. It also allows relatively long intervals of hours or days before backflushing [Miller-Leaman, 10]. With proper backflushing, the hollow fiber membranes have a 4-6 year design life while still meeting drinking water quality requirements.

To deactivate remaining virus the third stage is a germicidal ultraviolet light. The UV bulb is able to provide consistent ultraviolet output for 9000 hours before it needs to be replaced [Viqua, 8]. The ultraviolet energy attacks the microorganisms and destroys the DNA eliminating the ability to function and reproduce. This simple and effective process eliminates 99.99 % of harmful water borne pathogens [Crittenden, 4]. After passing through the three stages of filtration, the potable water that is given out to the public exceeds the drinking water standards set by NSF and EPA.

Normal filtration is straightforward with pumps circulating influent through the three stages. But achieving backflush capability with a simple sequence of valve changes requires careful design. Chemically aided backflush improves filter life so the design adds 6 ounces of chlorine to 30 gallons of purified water during backflush.

In addition to chlorine, air is blown through the filter at high velocity along with the chlorine and water mixture to increase backflush effectiveness. A sequence of timers and time-delay relays controls the 1 hour of forward filtration then 1 minute of backflush. The timer and relays implement an analog control system repairable in the field. The design includes no additional circuit boards or sensitive electronics to fail while in service. The backflush effluent is used by the locals for various applications such as agriculture and construction. Figure 1 illustrates the orientation of filtration components of the system.

The system uses a 25gpm inline pump to transfer unfiltered well water through the purifier. A 15gpm pump and an air blower are used for backflushing the system. These pumps and the blower are powered by a 20kW diesel generator. The UV bulb requires to be switched on at all times since turning the bulb on and off reduces the lifespan of the unit. For this reason, the UV bulb and lighting inside the container are powered using six 235Watt solar panels (Figure 2). The solar panels charge 8 deep cycle batteries which are able to power the UV bulb and the internal lighting continuously for 2 days during the absence of sunlight due to heavy rain or other weather calamities.

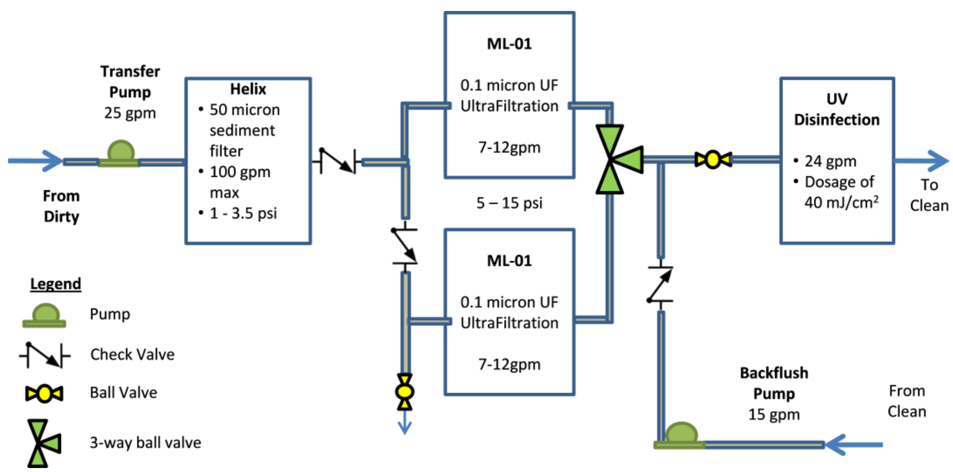

Figure 1 Water Flow Schematic

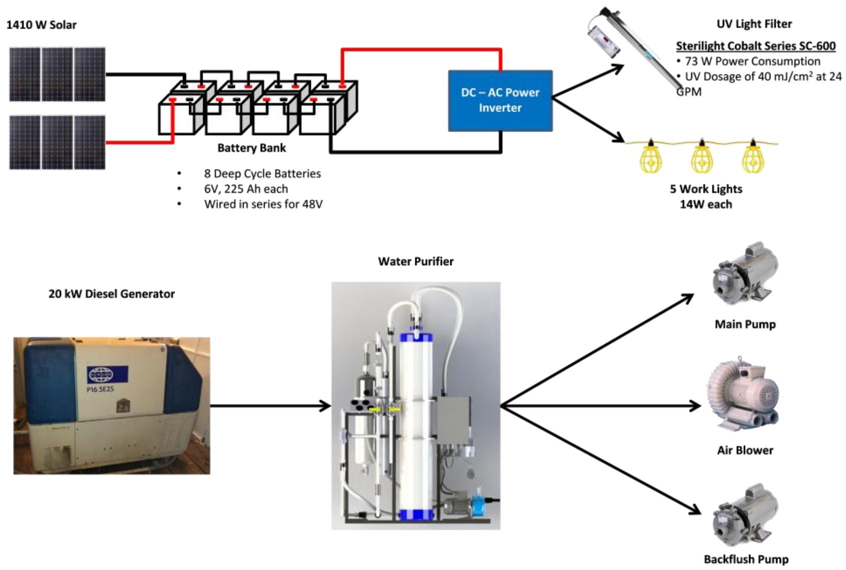

Figure 2 Power System Schematic

The main design goal was to manufacture a system that would be cost effective and highly efficient. A conventional water purification system depends on filter replacements in order to provide potable water. By utilizing the mentioned filter types, we managed to eliminate the need to replace filter cartridges. The UV bulb needs to be replaced after operating continuously for 365days and is the only filter component that requires replacement. The system is able to provide clean drinking water for 20,000 people with minimal maintenance costs.

The system was built and tested in a local water purification company which provided access to their frame fabrication and purifier test facilities. Their engineering and technicians provided valuable feedback and provided a corner of their shop in which to build the system. Once assembled, their wet-floor with water supply, drain, and red clay test dust provided valuable troubleshooting and adjustment prior to shipping the unit to Haiti. Red clay test dust appears similar to talcum powder and provides a known spectrum of particles calibrated between 1 and 100 microns.

Figure 3 Wet Table Testing with Fine Red Clay Dust

The red test dust was used for filter challenge testing on the UF filters. Because the UF filters are rated at 0.1 micron all red test dust was captured in filter mode. This also facilitated backflush mode testing. The wet table is where we finalized the backflush control sequence using air and water for 1 minute (Figure 3).

After installation, two Hach pathoscreen bacteria tests were performed to ensure water safety. After the 48 hour incubation period, side-by-side samples were compared with untreated water (Figure 4).

Figure 4: After 48 hours untreated water (left) indicated bacteria while the purified water (right) indicated no bacteria.

Installation and Training

A team of 13 traveled to Port-Au-Prince Haiti and stayed 5 nights at accommodations provided by NVM. The team was composed of 10 graduate and undergraduate students, 2 professors, one of which was a Haitian translator, and 1 professional engineer. NVM was a critical installation partner providing a fork truck, a flatbed truck, and a 20 kW diesel generator. They also arranged for two 20-foot shipping containers in which to store the purifier and diesel generator. The shipping containers were weatherproof and secure and provided the storage necessary for the purifier, and diesel generator. They also provided secure outdoor space for the solar panels and three 1000-gallon water storage tanks (Figure 5).

Figure 5: Three 1000 gallon tanks stored untreated and treated water. Two with clean, one with well water.

Figure 6: Local women and children lined up far in advance of clean water. This is their best supply of safe, clean water.

Prior to our arrival, NVM drilled a 350-foot well but only had a 1hp pump that provided only 5 gpm. This is much deeper than typical so the Embry-Riddle team brought a 3hp submersible pump increasing flow rate to 25gpm.

NVM provides ongoing oversight of the water purifier installation and used this investment in the Onaville community to start a micro-business selling water. The closest water source prior to this well was 1km away and was prohibitively costly. The free water was farther. All other local sources were likely contaminated. NVM now provides free well water and also sells purified water for a locally competitive price roughly half the cost of the next nearest source. Initial reaction to the purifier's clean water during installation was enthusiastic. Women and children primarily lined up immediately and kept filling buckets late into the night (Figure 6). Reports from Onaville after returning indicate they deliver roughly 3000 five-gallon buckets per day. Each bucket is 5 gallons, so the total water delivered daily is estimated at 20,000 gallons. The vast majority of that water is unpurified water because it is free. A smaller portion is the purified water for sale. This was an unexpected result and we are still learning each month as we receive reports from NVM about the ongoing operation and maintenance of the system.

We spent five hours training a group of local Haitians how to operate and maintain the system. With the help of our translator and NVM camp manager we are confident of a successful hand-off. We also provided a complete user's manual and maintenance guide and pictorial operation instructions (Figure 7).

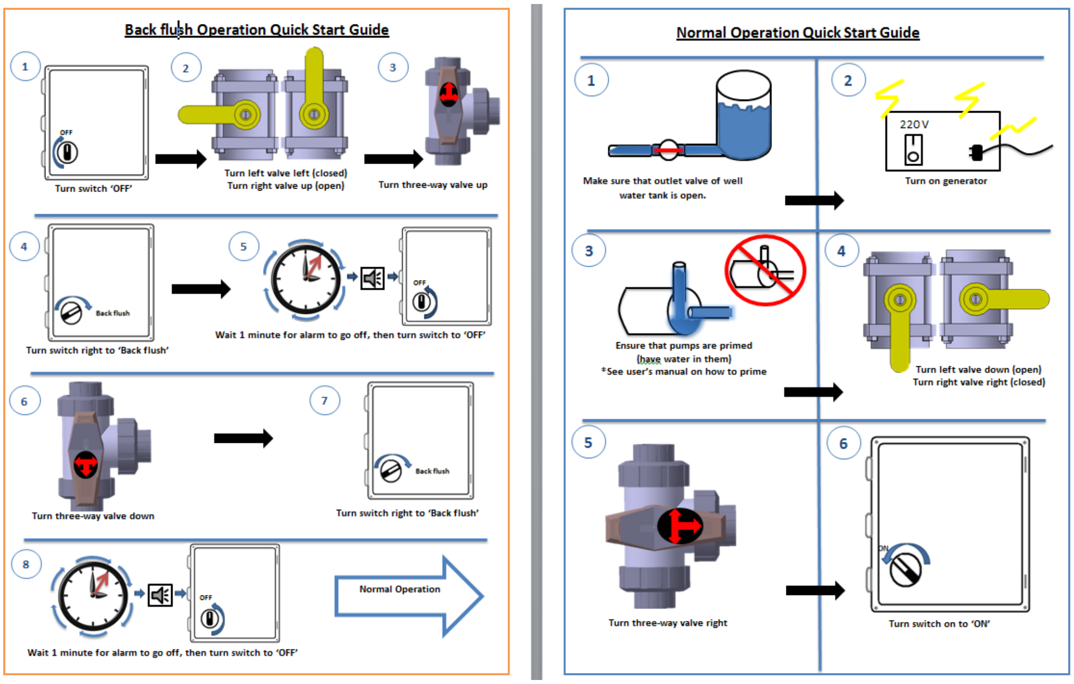

Figure 7: Pictorial Training Manual with Room for Creole Translations

We built the 'Army Jeep' of water purifiers. Its design is straight forward, able to be maintained in the field, has only a few special order components, allows for easy access to most components, and most of the plumbing has quick-connect joints. We are happy to say that, to date, the people of Haiti have been successfully maintaining and operating the system without any problems.

Observations on Growth

Project Haiti has grown as a student-led movement on campus over the past three years mainly as a Clean Energy Club project. It is a movement of students helping students gain access to clean water. The opportunity to help people directly with their engineering skills motivated the students to be successful. The goals in 2011 were to (1) provide the Haitian community with access to improved water, (2) solve a real world problem for a real world customer with real end-users, (3) provide the students' with the opportunity to experience a new culture, (4) increase student awareness of social responsibility, (5) educate new students on water purifier design and public health, (6) fundraise effectively for hardware and travel, and (7) attract prospective students to sustain the project into the future. These formed the basis for goals to achieve in future water purification projects.

Though students did not receive academic credit in 2010 or 2011, they were still extremely motivated as it allowed them to directly help people less fortunate with their engineering skills. The additional goals developed for the 2012 effort were (8) increased local community involvement, (9) to remove the need for replacement filters, (10) to train locals effectively on daily operation, (11) increased Haitian community development, and (12) to receive updates about the system after we left.

We found several of these goals to be in line with guiding principles developed by the Engineers Without Borders (EWB) and the Mortenson Center in Engineering for Developing Communities (MC-EDC), both at the University of Colorado at Boulder [Amadei, 2]. They propose a set of ten guiding principles for humanitarian development projects. Using these as Project Haiti evaluation criteria, our performance has improved over the last three years and still has room for improvement. The comparison in Table 1 below explains how Project Haiti has performed in the most recent 2012 trip using possible grades of *poor*, *moderate*, *good*, or *very good*.

Table 1: Project Haiti Evaluation Against Published Guiding Principles

EWB and MC-EDC Principles	Project Haiti 2012 Grade	Comments
1. Shared mission, vision, values and approach	*Very Good*	All students and sponsors had excellent shared vision.
2. Quality control and ethics	*Very Good*	Financial accountability was high; water pathogen quality achieved US drinking standards.
3. Organizational accountability	*Very Good*	Water system ownership was transferred upon successful installation to local Haitian leaders for long-term oversight and maintenance.
4. Education	*Very Good*	Both graduate and undergraduate students gained academic credit through a Practicum in Water Purification course during the assembly and test phase.
5. Innovation and technological appropriateness	*Very Good*	Plumbing and control electronics were designed for repair in-country with locally available materials.
6. Fundraising	*Moderate*	Project Haiti accomplished the dual purposes of sustainable humanitarian work and student education but raised only 20% of funds required from external sources.
7. Collaboration and teamwork	*Very Good*	Collaboration between internal and external stakeholders was high with the end-user's needs prioritized.
8. Duration of intervention	*Poor*	Project Haiti focused on a new installation site each year.
9. Sustainability	*Moderate*	Previous efforts in 2010 and 2011 did not maintain ongoing local support. Project Haiti 2012's primary installation partner owns and operates the installation site so U.S.-based intervention was replaced with ongoing local support.
10. Evaluation	*Poor*	Peer-team evaluation occurs briefly during the return trip but no third-party evaluation has ever been performed.

As Project Haiti continues to grow, the leadership needs to adopt guiding principles similar to the ones developed by EWB and MC-EDC. These will allow future teams to learn from previous projects, learn how to manage a humanitarian development project effectively, build a sustainably funded effort, and help students grow the project by defining their own specific goals focused on the end-user.

Benefits Gained

The success of Project Haiti 2012 was proved by benefits received by five involved stakeholder groups. First, the Haitians who previously lacked low cost, clean drinking water had their quality of life improved substantially. For most people living in developed countries it's hard to understand the daily reality of not having access to clean, safe drinking water. The Haitians now have access to clean water which improves their health and subsequently allows them to improve their standard of living either through education or more time for earning an income. Second, the engineering students who designed, built, and installed the purifier broadened their experience through a hands-on, collaborative project with a clear goal and deadline. They also broadened their experience through exposure to another language and culture and gained perspective by observing quality of life in a developing country. Third, the university gained positive recognition both in the local community and alumni network through newspaper articles, television interviews and alumni magazine articles. Fourth, the donors and hardware sponsors gained recognition through social media updates, newspaper articles, and also benefitted through tax deductions through the university's non-profit 501c3. Finally, the faculty involved received recognition for service, teaching, and fund raising. Gaining positive recognition is an intangible benefit that generated improves opportunity for both faculty and the associated students.

PEDAGOGICAL EFFECTIVENESS

The collaborative, hands-on nature of the project is a natural part of improving the quality of life for a Haitian community using a team of university students. Hardware fabrication and testing skills were necessary, as were promotion, fundraising, and international coordination and logistics. There was no formal assessment but it is clear from student interviews that the project and installation trip caused learning and growth not found in the classroom. Project Haiti had no formal assessment but qualitative research indicates high levels of personal growth and learning similar to more rigorous double-blind educational experiments [Schlect, 7].

In order to increase the benefits for students through Project Haiti, one faculty developed a course titled Practicum in Water Purification Design as a curricular companion to Project Haiti 2012 so that students could get academic credit for their efforts on pre-installation fabrication and testing. The course was developed through the pedagogical framework based on Kolb's experiential learning theory. As stated in Kolb's experiential learning theory, optimal learning would be achieved through a cycle of four stages (Figure 8) including the Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE) [Abdulwahed , 1, Kolb, 6]. The practicum course's contents and learning activities were designed to focus on stages of CE, RO, and AC while Project Haiti 2012 provided a learning platform of AE.

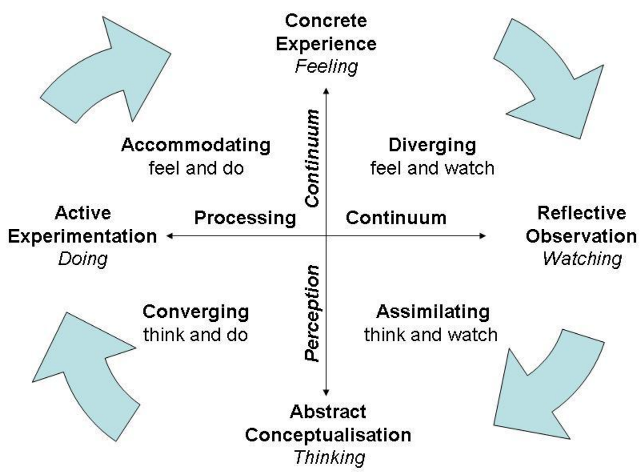

Figure 8 Kolb's Experiential Learning Cycle [3]

Teaching a summer course titled Practicum in Water Purification was a valuable way for both the students and faculty to gain university benefits of a course while developing the purifier. The summer Practicum gave students credit for constructing and testing the system mounting rack, solar power system, purifier components, and backflushing system. This was done partially on campus and partially at a local sponsor company prior to packing and shipping to Haiti. The design, component selection, and sourcing was done prior to the course. Shipping required an uncertain lead time and we chose 3 weeks for transport to Haiti's Port-Au-Prince receiving docks via a commercial shipping company. This left only 3 weeks during the early part of the course for assembly and testing. The scheduled departure on the 7-day installation trip was the day after the summer course ended. During the last 3 weeks of the course we used different water purification components in the lab. During this time we also focused on creating documentation after the purifier shipped. An engineering binder with data sheets for all pumps and purifier components was collected, along with CAD drawings and annotated figures illustrating the main components. A user's manual was developed that included basic installation steps, start-up, stopping, and backflushing steps illustrated using pictorial instructions only (Figure 8).

The Practicum course consisted of lecture session followed by hands-on session. For example, one lecture was to teach water borne pathogens and purification methods. In the hands-on session of the same week, the students immediately performed lab experiments that showed examples of the pathogens just discussed in class. One assignment was to take water samples and grow bacteria from the sample in a petri dish for 3 days. This was done with water test kits less than $15 available at a local hardware store. At the end of the week, students presented photographic records of growth on their water samples after 12, 24, and 36 hours. The assignment also asked them to identify the water-borne pathogen from the bacteria's morphology. This is an ideal case of Kolb's experiential learning model where course material was covered in class, a hypothesis made as to what bacteria might lie in a local pond, an experiment started to grow live bacteria, and the assignment to consider and report on what actually grew on their petri dish. As students presented petri dish photos, we all were surprised at what grew in each sample. Theory, then experimentation over multiple days, then study and presentation of their results completed the example of Kolb's cycle of experiential learning.

SUCCESS FACTORS

Project Haiti 2012 was a big success as all the involved stakeholder groups have gained benefits relevant to their role. We truly realize that the success would be impossible without the academic and financial support from the university administration, industrial partnerships, and community involvement, in addition to having a team of highly motivated students and faculty.

ERAU's administration has provided great support to Project Haiti. In addition to provide half of the funds for hardware and travel support, the administration made a quick approval for the Practicum course to benefit the involved students with class credits which is more attractive than study abroad program. Through Project Haiti 2012, the university gained positive recognition both in the local community and alumni network through newspaper articles, television interviews and alumni magazine articles.

Project Haiti 2012 also motivated corporate sponsors to participate with donations of cash, hardware, or in-kind engineering support when they learned about the project and saw the passion in the students. Their support financially for the other half of funds for hardware and transportation and the in-kind hardware support for filters, solar panels, pumps, and manufacturing validated the theme of the project to be "High Tech, High Touch."

Having installed two previous water purification systems in Haiti, we received widespread local recognition through the local newspaper, television, radio, and was able to present at various luncheons, conferences, and community events. This outreach to the community helped us gain financial and hardware support that were instrumental in helping the project towards successful completion. The community stakeholders helped the students to touch the lives of people who are less fortunate than they are while contributing to solve a world problem.

CONCLUSIONS

Haitians live with chronic illnesses from consuming water ridden with bacteria and viruses. They have no other choice but to drink this bad water. This ongoing project at Embry-Riddle to provide communities in Haiti with access to clean water has changed the lives of many thousands of people. Clean water improves the health of those who consume it, especially children. With improved child health, an entire community and culture improves because their energy level and education will improve. For children and adults, this translates into a higher quality of life, as they can now spend more of their time getting an education, working to make money, and also taking care of their family.

The Project Haiti 2012 team designed, tested, and delivered a 20gpm water purifier with 3hp submersible well pump. The purifier has backflush capability and, combined with locally available chlorine (Clorox) has a design life of 4-7 years. One 1000-gallon tank stores well water for use directly for making concrete or other washing needs.

Two 1000-gallon tanks store the water purifier's output. A faucet rail was constructed to facilitate culturally appropriate bucket filling. The system serves approximately 3000 5-gallon buckets a day. It was installed and stored in a weatherproof, secure shipping container.

The installed purifier has also provided jobs and improved the community immediately. Even before the system was installed, the local leadership began drawing well water to start construction on the compound. The entire interaction with locals was an important educational period for the US-based engineering students. They saw their positive impact on the locals who previously only had access to contaminated water or very expensive clean water.

An annual summer trip to Haiti provides the benefit of known logistics, housing, translation, and security measures. It has provided exceptional learning experiences and positive publicity for the University. Our intention is to continue a yearly trip with university engineering students and trusted Haitian partners so Project Haiti will continue to provide clean drinking to those that desperately need it.

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Yung Wong

Mr. Yung Wong graduated with a Bachelors of Science in Mechanical Engineering, with a concentration in Clean Energy Systems, from Embry-Riddle Aeronautical University in 2012. He is continuing with his Master of Science in Mechanical Engineering with an expected graduation of Spring 2014. He has been a part of the past two water purification systems to Haiti and has held a leadership position in each of those two years. His interests include water purification, renewable energy technology for electricity generation, and project management. He is currently in the process of creating a business focused on designing sustainable water purification systems.

Johnathon Camp

Johnathon Camp is a senior in Mechanical Engineering department who will start his Masters in the fall. He has contributed to the design and implementation of two solar powered water purification systems in Haiti and is a team member supporting the design of solar powered water purification backpack. In addition to water related projects he is also the mechanical team lead for EcoCar2 at ERAU, a developmental program designing a series plug-in hybrid vehicle.

Shavin Pinto

Shavin Pinto graduated with a Bachelors of Science in Mechanical Engineering with a concentration in clean energy systems from Embry-Riddle Aeronautical University in 2012. He will graduate with a Master's of Science in

Mechanical Engineering in Fall 2015. Shavin is actively involved in various projects related to clean energy. He is currently a graduate research assistant working on a patent pending design for a portable water purification backpack.

Kyle Fennesy

Mr. Kyle Fennesy is a junior in Mechanical Engineering with a concentration in Clean Energy Systems at Embry-Riddle Aeronautical University. He has previous experience in robotic mobility systems and has worked at Johnson Space Center for a summer in the Robotic Systems Technology Branch (ER-4) of NASA. He anticipates graduating in December 2015 and plans to attend graduate school at Texas A&M University.

Dr. Marc Compere

Dr. Marc Compere is an Assistant Professor of mechanical engineering at Embry-Riddle Aeronautical University in Daytona Beach, Fla. Compere's current research in sustainable technology focuses on water purification, concentrated solar power for electricity generation, water desalination, and solar powered air conditioning. He has developed and delivered two of Embry-Riddle's solar powered water purification systems to Haiti with university students. His background is in modeling and simulation, hardware-in-the-loop and driver-in-the-loop control systems, robotics, mechatronics, vehicle dynamics, and hybrid electric power system dynamics.

Dr. Yan Tang

Dr. Yan Tang received a B.S. degree and a M.S. degree in automatic control theory and application from Nanjing University of Science and Technology, Nanjing, China, in 1995 and 1999, respectively. She received a Ph.D. degree in mechanical engineering from University of Central Florida, Orlando, Fla., in 2009. She is currently an Assistant Professor in mechanical engineering at Embry-Riddle Aeronautical University, Daytona Beach, Fla. Her research interests include intelligent control, robots, and applications of biomimicry techniques in engineering.