2020

University-Community Partnership For Water Technology Deployment And Co-Innovation: A Decade Of Engagement

Paul M. Cabacungan
Ateneo de Manila University

Gregory L. Tangonan
Ateneo de Manila University

Nerissa G. Cabacungan

Custom Citation

Paul M. Cabacungan, Gregory L. Tangonan, Nerissa G. Cabacungan, (2020), University-Community Partnership For Water Technology Deployment And Co-Innovation: A Decade Of Engagement. International Journal of Advanced Research and Publications (IJARP), Volume 4 Issue 5, 81-90.

University-Community Partnership For Water Technology Deployment And Co-Innovation: A Decade Of Engagement

Paul M. Cabacungan, Gregory L. Tangonan, Nerissa G. Cabacungan

Ateneo de Manila University, Ateneo Innovation Center,
Loyola Heights, Quezon City, Philippines 1108
pcabacungan@ateneo.edu

Ateneo de Manila University, Ateneo Innovation Center,
Loyola Heights, Quezon City, Philippines 1108
gtangonan@ateneo.edu

Ateneo de Manila University, Ateneo Innovation Center,
Loyola Heights, Quezon City, Philippines 1108
ncabacungan@ateneo.edu

Abstract: The Ateneo de Manila University (Philippines), through its Ateneo Innovation Center (AIC), integrated existing simple technologies into one system – the Water-Electricity-Lighting System (WELS) – to respond to the need for potable water, lighting and communication. WELS is a portable clean water system with provision for lighting and cellular phone charging. It can be connected to a rainwater harvesting facility. Ten years of WELS deployments revealed its flexibility for customization in order to address varied water needs, especially for disaster response. Review of documentations done on past installation experiences highlights the value of engagement between university-based technology providers and community-recipients. This engagement leads to technology improvement and sustainability through co-innovation and contributes to community resilience and education through hands-on training. This paper narrates a decade of deployment experiences and presents the process of community involvement. We present a model of engaging the stakeholders that brings mutual benefit to both university and community through this partnership.

Keywords: Co-Innovation, Community Empowerment, Innovative Water Technology, University-Community Partnership

1. INTRODUCTION

"Water all around but not a drop to drink." This describes the predicament of someone stranded in the middle of the sea. This scenario has become a frequent occurrence in many parts of the world after flash flood, tsunami or other natural calamities. Access to drinking water is a concern emphasized after a calamity (Nasronudin, Juniastuti, Oktamia, R. H. & Lusida, M. I., 2012). This also paints the daily struggle of island dwellers. They may be rich in sources of water but water quality is not safe for drinking. In the Philippines, access to clean water is a long-standing concern. Around ten million Filipinos lack access to safe water (WHO, 2019). Instead of promoting health, some water used for drinking even cause illness. About 80 percent of diseases are caused by contaminated water, according to the executive director of the United Nations Environment Program (Tacio, H.D., 2018). Due to water scarcity or danger of water-borne diseases, a total of 2.6 million Filipino households resort to bottled water (PSA, 2019). This can aggravate the current waste problem and the concern on the presence of microplastics in bottled water, not only in tap water (Eerkes-Medrano, D., Leslie, H.A. & Quinn, B., 2018). This paper describes an initiative to respond to clean water needs through a university-developed water technology that is deployable to communities. This technology includes integration to a rainwater harvesting facility. The process of engaging the community through university-community partnership towards technology transfer is also presented. No conflict of interest is to be declared because the proponents of this paper conducted the research as part of their office function and worked with communities that were in partnership with their home institution.

2. LITERATURE REVIEW

2.1 Water Technology

Water-Electricity-Light System (WELS) uses water treatment methods found effective in literature. It is a much better alternative to chlorination. Chlorination, which is a universally accepted chemical water treatment method (Franken, L., 2005), generates harmful disinfection by-product (Havelaar A.H., et. al., 2000) and leads to the formation of chloroform -- a known carcinogen (Freese, S.D. & Nozaic, D.J., 2007). Instead of chlorination, WELS combines ultraviolet irradiation and ceramic filtration to disinfect water. There are many pathogenic organisms that are more susceptible to ultraviolet (UV) than they are to chlorine (Pieterse, M.J., 1988). UV irradiation is quickly gaining popularity in the consumer market as a safe, effective, and economical approach to disinfection (Sobsey, M.D., 1989). Ceramic filtration, on the other hand, reduces e-coli up to 99.9% (Brown. J.M., 2007). Both water cleaning methods are part of the WELS unit.

2.2 Rainwater Harvesting

Rainwater harvesting (RWH) is seen as an "economical and sustainable" way of obtaining water in Indonesia (Song, J.M., Han, M.Y., Kim, T. & Song, J.E., 2009). In France, after a detailed analysis of RWH application in eight countries (Australia, Brazil, Germany, India, Sri Lanka, Uganda, United Kingdom and United States), it was recommended that RWH be integrated into its urban water management approaches ((De Gouvello, B., Gerolin, A. & Le Nouveau, N., 2014). In developing countries, especially in Africa and Asia, community-based rainwater harvesting is considered an innovative solution to develop sustainable drinking water supply systems (Kim, Y.K., Han, M.Y., Kabubi, J., Sohn, H.G. & Nguyen, D.C., 2016). In the Philippines, mean annual rainfall varies from 965 to 4,064 millimeters annually (DOST, 2014) and this water resource is being wasted. In 2019, the House of Representatives approved House Bill #4340 requiring subdivisions, condominium communities, malls, government institutions and central business districts to construct rainwater harvesting facility (HB 4340, 2019). Ten years earlier, WELS had already been integrating rainwater harvesting into its clean water technology.

2.3 Community Engagement

Medina (2019) pointed out that higher education institutions (HEIs) have a fundamental role to create knowledge, through research, for the development of communities, especially the underserved. Within this collaboration of HEIs and the larger communities, mutual benefit is served through exchange of knowledge and sharing of resources in a context of partnership. It is important that, in this engagement, the community understands the purpose of the initiative. Engagement develops a sense of ownership where the community commits to the process and the outcome and works toward achieving success (Medina, 2019). This paper traces back the process of community engagement before the successful transfer of WELS to the community. In summary, the water system that is to be presented in this paper uses methods that, based on literature, are effective. The system integrates lighting and cellphone charging. It can be connected to a rainwater harvesting system for sustainable water supply. Community engagement done, for the eventual transfer of this water technology to the target community and for the mutual benefit it brings, is illustrated.

3. METHODOLOGY

We sifted through all the documentations done in relation to a decade of deployments and installations of Water-Electricity-Lighting System (WELS) all over the Philippines. We read through the reports, magazine articles, interview and personal notes. We reviewed email exchanges as we coordinated and planned with donors and recipients. We recalled feedback and comments given by the communities. We shared lessons learned from all these deployment experiences. This paper also highlights the initial works and processes leading to technology transfer. We narrate the important groundwork needed like networking with benefactors or donors, preparing for deployments, coordinating with and engaging the community-recipients and transitioning to technology transfer.

3.1 Technology: Water-Electricity-Light System

WELS is a portable clean water system with provision for lighting and cellular phone charging. It has the following components – rain catcher, mechanical filters and UV irradiation, solar panels, charge converters, LED lights, inverter, and car battery. Components that are included during installation depend on the recipient's needs and context. This system is an offshoot from a water generation device fabricated for a graduate thesis in the Ateneo de Manila University (Philippines). It aims to address crucial water needs – for emergency use during disaster and for daily use in areas without safe drinking water sources. WELS can be connected to a water storage facility or a damaged municipal water source. Components are acquired off-the-shelf so replacement parts are accessible. The cost of the whole system is reasonably affordable ranging from US$600 to US$700 depending on components to be included. This system illustrates a concrete way to build disaster resilience in a community level. Training is conducted to learn operation and repair. WELS is easily replicable and technical support is readily available through QR code access. The operation diagram of the system is seen in Figure 1. In depth discussion on the technical aspect of the system can be found in Cabacungan, Tangonan and Cabacungan (2020, in press).

Figure 1: *Operation diagram of Water-Electricity-Light System*

3.2 Deployment Experiences

In a span of ten years, there are more than one hundred forty (140) WELS installed in different parts of the Philippines (National Capital Region, Luzon, Visayas and Mindanao) serving varied purposes.

3.3 Everyday Use Installations

The first installation happened in 2008 in El Nido, an island in Palawan, Philippines. The rest house had no electricity and municipal water but had a rainwater harvesting facility. Insufficient pressure to feed water into the system was a major hurdle. We shifted from a gravity-feed approach to using a submersible pump, run by fuel-powered generator, to push water and feed into the system. Two components of the system – the compact fluorescent light (CFL) and the electronic battery charge monitoring device – consumed too much energy that easily drained the battery. We replaced the CFL with a more energy-efficient LED bulb. The older model of battery charge monitoring device was replaced with a newer and more energy-efficient models. Realizing the potential of the system in this very first experience, installation in other off-grid communities followed. We saw a common problem faced by residents in remote areas – due to lack of access to clean water, drinking water turns out too expensive. For instance, the president of a private college in Palawan (an isolated island in the Philippines), shared that scarcity and high price of drinking water forced the students and residents to consume more soda, which is cheaper, than water. This led to many cases of urinary tract infection. Also, island residents would transport gallons of water by boat and pay more. In Talim Island in Rizal province, a Php25-container of water in town port costs Php40 when it reaches the island. In Isla Verde, from Php25 in Batangas City, a 20-liter of water becomes Php75. When inclement weather prevents transporting of purified water, residents would drink untested ground or spring water. We encouraged the communities to use rainwater instead of ground water. We instructed them on the proper manner of water collection and proper set-up and maintenance of harvesting storage. In cases where even the rainwater from the house roof is coliform-contaminated, usually caused by livestock raising in the vicinity, we suggested to use chlorination. We verify the right chlorine concentration using a test kit for chlorine. The activated carbon filter of WELS lessens the chlorine content to make it safe for human consumption. Then, the UV light kills Cryptosporidium parvum oocysts, which are resistant to chlorine. Water tests helped reinforce the idea that the rainwater should be kept separate of local water sources. We brought biological water test kits during installation in Talim Island. Results mainly showed that their local water sources were badly contaminated, having been that way for a long time. Talim Island residents were surprised to learn that they drink from e-coli-contaminated water sources. One of the recipients of WELS realized that it could be the reason why he suffered from severe diarrhea in the past and was even hospitalized. He said he was even lucky because others would not make it to the hospital. Another resident added that there was a time of "diarrheal epidemic" in the island. Only after they were educated in the use of water test kits did they become aware of detecting water contamination and realize the dangers of drinking contaminated water. Sample water test kit indicating results of contaminated and cleaned water is found in Figure 2.

Figure 2: *Water test kits showing results of contaminated (above) and cleaned water (below) in one installation site*

In the NCR where electricity and tap water are available, only the WELS filtration and disinfection components were used in many residential houses. For drinking water consumption of babies and the elderlies, city dwellers buy distilled water by the liter/gallon. Connecting the 3-stage filtration system with UV lamp to the household faucet assured very clean water. This new appreciation of UV disinfection was expressed by many, especially pregnant women, as they say, "Make sure the blue light (from UV lamp) is operating, it means the water is super clean". Bigger filters were installed in a residential house in Novaliches that used brownish ground water for laundry which caused discoloration to their clothes. When WELS was connected, water became clear and no more discoloration was experienced. In Pandi (Bulacan) relocation site, water distribution follows a schedule. The presence of WELS gave greater access to drinking water and an alternative source of livelihood. A homeowner and WELS recipient in Pandi reported that she made a business out of WELS by selling drinking water to neighboring communities. The university-recommended business model of selling cleaned water supports sustainability of the system and a return of investment for the entrepreneur in six months. Shown in Figure 3 is the thriving water selling business in Pandi, Bulacan.

Figure 3: *Water selling business (showing list of sales) in Pandi (Bulacan) leads to sustainability*

Over the years several new strategies for cleaning rainwater evolved. Realizing it takes only a motorcycle battery to clean water, portable water cleaning stations are viable. The entrepreneur takes the complete system to homes with stored water and cleans 50 liters or more in 15 minutes for a small charge. Twenty or more homes can be serviced this way with one battery. In Isla Verde, WELS operates daily. Since the key to this system is stored energy that can be transported, we developed a battery-charging system using a bicycle that can be used 24/7. We see a demonstration of this system in Figure 4.

Figure 4: *Pedal-powered alternator installed at Isla Verde, Batangas*

3.4 Post-Disaster Response Installations

The installations of WELS in disaster-stricken areas - like in post-Sendong (Washi) Cagayan de Oro in 2011, post-earthquake Bohol and post-Yolanda (Haiyan) Tacloban City in 2013 (all are Philippine provinces) – were done immediately after the disaster and were met with great challenges. Quick response was always crucial. When news reached us of the devastation in the affected areas, we immediately go there, using our personal resources and financial donations from colleagues. Later on, our home institution established a "fast-track" cash disbursement for immediate deployment of WELS. Finding a contact person in the disaster-stricken areas was also crucial. We looked for contacts of our institution in the affected areas, usually coming from academic or religious institutions or local government units who would be willing to accommodate us. We keep a directory of contact persons for future communication and networking. We realized that even with the presence of contact persons, delay of installation was to be expected. Everybody was busy in giving assistance in time of disaster. There were also instances where key people themselves were affected so they cannot perform their functions. Moreso, we saw the wisdom of pre-positioning this asset in the community to provide immediate relief. Transporting the equipment and tools was another challenge. Filtration and disinfection systems break easily so airports require them to be checked in. When we told airport personnel that those were meant to provide drinking water in the disaster areas, they reconsidered. During initial deployments, only one installer would go to deploy the system. Carrying and watching over the materials was a major concern. A buddy system – with one main installer and an assistant – was applied for every installation. Uncomfortable accommodation and unpredictable means of transportation were to be expected. We experienced sleeping on the grass outside the hospital in a post-earthquake Bohol and hurriedly rode with a victim in an ambulance to catch a flight out of Tagbilaran City after post-disaster installation. Institutions that are open to the public were chosen as installation sites for WELS -- schools, convents, barangay or municipal halls, hospitals, resettlement areas and police stations. Careful planning of itinerary was needed to install in different sites by going from one place to another in one sweep. Post-disaster response necessitates quick installations to cover more sites, thus, work continues even at nighttime. As shown in Figure 5, WELS was connected to a water tank rationing drinking water to the community after a disaster in Cagayan de Oro. Residents started fetching water immediately after installation.

Figure 5: *Nighttime installation in post-disaster Cagayan de Oro*

3.5 Pre-Positioning Installations

Twenty schools in Marikina and San Mateo (NCR) had pre-positioned WELS units. WELS with solar powering provision was attached to the school's tap water or rain catcher. There were frequent occurrences of heavy monsoon rains in the past that caused flash flood in these areas. Affected families were displaced and temporarily sheltered in schools, which served as evacuation centers. When we installed WELS immediately after a flash flood incident, school principals saw the wisdom of having them as pre-positioned assets. When schools turn to evacuation centers again, they can readily provide drinking water even if municipal water gets contaminated and the electricity service is disrupted. On regular schooldays, it gives additional cleaning and disinfecting to students' drinking stations. Principals and teachers, though non-technical, attend hands-on training to facilitate WELS installation in their respective schools. Figure 6 shows participants representing nine schools in Marikina City.

Figure 6: *Training of principals and teachers for WELS pre-positioning in schools*

In Valenzuela (Metro Manila) buying and bringing water every day to their community was alleviated using their rain catchment. Figure 7 shows a TV interview with the rain catchment at the background. One resident quipped, "Kapag umuulan, mahirap lumabas, puwede na dito sa loob bumili ng inumin" (When it is raining, it is hard to go out, at least we can buy drinking water within the community). The locals started a thriving water selling business. Similar pre-positioning installations done in Valenzuela (NCR) were applied in GK communities in Angat, Bulacan (Luzon) and Capiz (Visayas), LGUs in Pila, Laguna and Magdalena, Sorsogon (Luzon), and in some barangays in Aparri and Benguet (Luzon). Some systems are not regularly used but are properly maintained to be used in times of emergencies while others are in operation for daily usage.

Figure 7: *TV interview regarding WELS (shown behind interviewee) in Valenzuela*

Based on our past installation experiences, we saw more advantages in pre-positioning of WELS than installation for emergency post-disaster situations. The next table summarizes the learning gained from pre- and post-disaster installation in key parts of the process.

Table 1: *Difference in experiences between pre- and post-disaster installations*

	POST-DISASTER	PRE-DISASTER
FUNDING AND BUDGETING	Personal; home-institution donation; fluid budgeting due to unpredictable expenses; financial and material resources solely provided by donor	Corporate social responsibility, barangay or local government project, NGO support for adopted communities; definite budget because of certainty of expenses to be incurred; financial and material resources can be shared by donor and recipient
LOGISTICAL PREPAREDNESS	Personally arranged; uncertainty of arrangement done by community; no ocular inspection -- adjustment is done as installation progresses	Well-arranged before deployment; Memorandum of Agreement stipulations; defined responsibilities of both parties; ocular inspection or discussion on installation site to anticipate and address possible obstacles
DEPLOYMENT	Safety of deployment team and materials on personal account; no definite accommodation/ transport service; fluid itinerary with expected delays; point person may not be around during actual installation causing alterations afterwards; Manila-based installers	Deployment needs are explicitly discussed and safety protocols are arranged; identified contact person to take care of the deployment team; clear itinerary with transportation arrangement; point person oversees the actual installation to avoid alterations afterwards; shared manpower -- main installer from Manila, local skilled workers from installation site
TRAINING	Accidental participants -- whoever is available at the time of turn-over; due to time constraint, training focuses on system assembly and operations only	Identified participants - purposive selection of participants based on assigned responsibilities, required skills to enable system replication, or department assigned to oversee the system; training covers system assembly, operations, trouble shooting, repair
TURN-OVER	No formal/official turn-over; system is left for use without clear discussion on sustainability	With formal/official turn-over and clear discussion on sustainability and business model for livelihood
PARTNERSHIP	Informal; no continuing feedback-giving or sustained communication	Formalized; continued discussion for co-innovation and feedback-giving; continuing consultation

All WELS installations included training in system operation, maintenance, and repair with complete materials list. A tarpaulin showing the components and maintenance procedures, together with the installer's contact details, was also posted in the installation site for easy reference. A sample of the reference poster made for the initial trainings is in Figure 8. This eventually improved to include more pertinent details like installer's contact information and QR code access for updates about the technology.

Figure 8: *First reference poster used during trainings*

3.6 Learning and Innovations

Deployment experiences gave rise to innovations and customization. What follows are the processes of development in the different stages of deployment.

3.7 Wider Collaboration: From Personal to Funded Donation

Initial installations started with personal initiative to extend a helping hand during calamity, with a belief that the system can address the need for drinking water. When its importance was recognized, partnerships were forged with local government units (LGUs) or with the community or institution. Installation cost was shouldered by the respective LGU or institution. Later on, non-government and civic organizations (like UN World Food Program, Foundation for the Development of Urban Poor, Philippine Support Service Agencies and Gawad Kalinga), funded installations in their adopted communities or selected beneficiaries. Some corporations or companies, like Astoria Plaza, Gallego Architects and Honda World, donated WELS units as part of their Corporate Social Responsibility. Even our home institution's Ateneo Disaster Response And Management (DReAM) Team funded installations in evacuation centers in different areas. Moreover, as part of AIC's continued innovative research on WELS, funds are sourced for installation.

3.8 Preparatory Work: From Transported to Shared Resources

Once funding is settled, we purchase needed components and materials. We double check if tools are complete and reliable. We bring spare consumable parts to the installation site in case of breakage during transport. We bubble wrap breakable components and put in hard-covered bag to avoid being pressed on. We pack them securely and tightly for land, water or air transport, minimizing movements. Electronic parts are kept dry. We hand carry delicate components like ceramic filters and UV lamps. We always have a travel companion to help secure all the materials. Safety gears and equipment, like ladder and waist band, are necessary when installing solar panels, especially when installation is done in high places or in earthquake-ravaged areas. In Bohol, we experienced aftershocks while on top of a roof and installing solar panels, safety gears with prayers kept us alive. First aid kit is a must. Post-disaster deployment can be met with challenging weather condition or unfavorable physical condition. Travel light but with a blanket that can keep you warm, which you can also leave behind as donation. Bring a personal go-bag packed with water and emergency food. Victims are prioritized in relief good distribution. Chance to do ocular inspection is an advantage in order to know plumbing and electrical lay-out and find the best location that has maximum sunlight exposure for the solar panel. If inspection is not possible, site description through discussion and pictures can help AIC plan out the process of installation. This is more feasible for pre-positioning of WELS, not for disaster response. Identification of skilled workers on site and their availability and daily wages can also be agreed upon even before installation begins. All needed materials and equipment used to be brought from Manila to the installation site. Door-to-door delivery service, if available in the area, can be explored by sending some equipment ahead of time. However, from experience, relying on such service may result to delay in delivery and/or breakage of equipment being transported. Thus, close collaboration with community-recipient is more advisable. Provide the contact person on-site with the list of needed tools and equipment and identify which ones are available in local hardware stores within the vicinity to lessen materials to be transported in a long haul. In some islands, car batteries were purchased in the mainland. Cost was higher but risk of damage was less and the burden of transporting them at a long distance was avoided. Service vehicle is an advantage due to limited transportation in remote areas. If contact person cannot provide a vehicle, rent out a vehicle on-site which the contact person can pre-arrange. If this is still not feasible, coordinate with agencies involved with quick disaster response and see if equipment or personnel can be squeezed in their service vehicle meant for rescue or relief operations.

3.9 Community Involvement: From Educating to Partnering

The community's involvement goes through levels which resembles a parallelism with the Public Involvement Continuum Framework cited in Health Canada 2000 (Born, K. & Laupacis, A., 2012). The framework is illustrated in Figure 8. This process happens when pre-deployment planning is involved and may not be applicable for immediate and emergency disaster response.

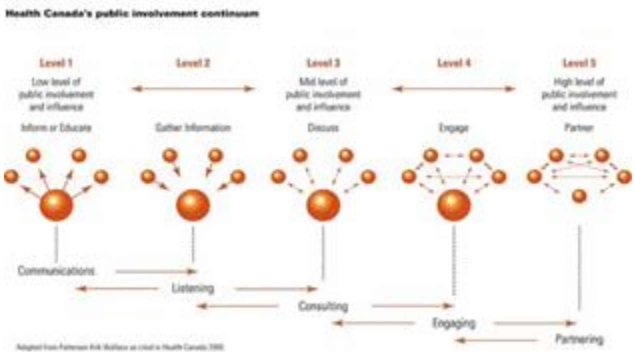

Figure 9: *Public involvement continuum framework cited in Health Canada 2000*

<u>Level 1: Information and Education</u>. The initial encounter is between AIC and the benefactor/donor and/or authorized decision-maker in the community. At this stage, the AIC presents the system and explains how it works. It is a one-way communication where the AIC educates while the other party receives information. Sometimes, the other party is familiar with WELS and just asks for possible customization.

<u>Level 2: Gather Information.</u> The AIC learns more about the context of the prospective community-recipient at this point. Listening to the need of the community makes it easier for AIC to see the appropriateness of WELS to address the community's water needs. WELS's limitation in cleaning ground water and in removing certain contaminants or pollutants is clear so AIC is on the lookout for such condition in the community. AIC also assesses possible hurdles that may be encountered onsite and proactively prepares resolutions for anticipated obstacles.

<u>Level 3: Discussion.</u> At this point, discussion revolves around installation scheme that is presented to and approved by the benefactor and/or community leader. Agreement in the terms and conditions set by both parties is confirmed and sealed with the signing of the Memorandum of Agreement (MOA). The MOA stipulates guidelines and conditions to operate within. Logistical details are also discussed, such as, availability of materials and equipment in the area, the existence of storage facility for the equipment, and presence of skilled personnel (like plumber and technician). Transportation and accommodation arrangements are also clarified. It is reiterated that community decision-maker must be present during installation to avoid delays or unnecessary reconfigurations afterwards. Sometimes, the AIC is invited to present the project to the community where levels 1, 2 and 3 of the process can happen all at once.

<u>Level 4: Engagement.</u> At this level, the community becomes involved in the WELS installation. AIC trains the residents and supervises them as they do the actual installation themselves. Tapping their skills and sense of volunteerism empower them and make them the "local heroes". Engaging them gives them a sense of ownership and greater commitment to care for the system. This was evident in Ecoville resettlement area in Cagayan de Oro where local youth worked together to install the WELS and to build a "housing" for it in the relocation site's common kitchen facility. The youth's confidence in installing the system was evident as seen in Figure 10.

Figure 10: *Youth installed WELS in a relocation site's common kitchen facility*

In every site, hands-on training is a must before and after installation. With or without technical know-how, recipients go through training to learn about the system's installation, operations and maintenance procedures.

Figure 11: *Hands-on training educates the community*

They oversee the actual installation or participate in hands-on demonstration. In some cases, after the training, people replicate the process and do the installation in their respective community, like what happened in Javier (Leyte). Sometimes, students in universities near the installation site are gathered for a short lecture. Discussions can stir interest and arouse awareness to inspire future initiatives. After the training, a tarpaulin and manual of instructions (written in English and Filipino -- the local dialect), containing component specifications and operational and maintenance procedures, are turned-over to the caretakers. The installer's contact information is also given.

Level 5: Partnership. At this stage, AIC and the community-recipient stand on equal footing where AIC provides the technology while the community-recipient suggests further development of the technology. In recent installations, we saw the benefits of co-innovating with partner communities. Both parties work together to solve a problem of mutual interest and engage in a constant feedback-giving. They co-innovate and develop the technology further. It is a two-way communication where AIC listens to the feedback and suggestions coming from the community and, on the other hand, gives recommendations to ensure WELS sustainability, which the community acts on. Such process was evident in Pandi where the recipients suggested more appropriate water storage. On the other hand, the community tried out the AIC's business model. As the viability for business and the sustainability of WELS are being studied, the partnership between AIC and Pandi continues. Complete transfer of technology also happens at this stage. The community-recipient becomes self-reliant and works towards replication of the system. This was true in Kibungan, Benguet where the LGU sought funding to install more systems in the province. The LGU installed additional systems by themselves with AIC as consultant.

3.10 Technology Development through Co-Innovation

Continuous development and customization are applied on WELS based on the concerns raised and feedback given by the community. Co-innovation with the community happened. Construction of concrete rainwater storage facility is costly and may pose concerns. In Leyte, we saw a rainwater storage facility that has cracks and the walls are full of moss. We fabricated an improvised rainwater storage using drums for easy maintenance cleaning as shown in Figure 12.

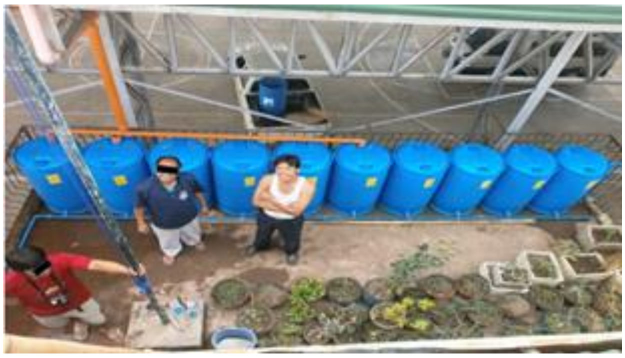

Figure 12: *Rainwater harvesting using drums directly attached to roof downspouts*

For installation sites with livestock nearby or where roof is prone to bird droppings, tarpaulin is used as water collection tool. When it starts to rain, tarpaulin that was kept inside the house is cleaned and spread out to catch rainwater directly from the sky, not from the roof's downspout, then pour water down into a drum. This approach is seen in Figure 13.

Figure 13: *Improvised rainwater collection using tarpaulin and drum*

In Iloilo, a cistern is constructed before a covered court is cemented to have stored rainwater for drinking even during summer time. For household use, small water container can be attached to a do-it-yourself pump to suck water out then into WELS for cleaning as illustrated in

Figure 14. With the use of DIY pump, WELS can circulate in the community and clean water from any clean container.

***Figure 14:** Do-it-yourself PVC pump to clean water from any container*

Some residents in Pila, Laguna complained that transporting water is heavy, so we made a mobile clean water system by putting WELS in a wheeler or tricycle as seen in Figure 15. Water cleaning kit in a backpack can also be included in a "go bag" in time of disaster.

***Figure 15:** Clean water disaster kit (left) and mobile clean water system (right)*

WELS started with grid electrical powering. Installation in off-grid communities necessitated alternative power sourcing, thus, the use of solar panel. Residents wondered how they can clean water when it is cloudy. Insufficient sunlight for 3 days can drain the battery, so we suggested battery swapping. Later on, we transitioned to pedal-powered alternator charging, which is available at nighttime and rainy season. This manner of battery charging works well in Isla Verde. Some WELS recipients complained about the high cost of UV lamp. It led us to conduct experimentation on a cheaper aquarium disinfecting lamp and the results are promising (Cabacungan, et.al., 2020. in press). Questions were raised about detecting the safety of drinking the water that passed through WELS. We brought portable water testing kits during installation that show results after 24 hours.

3.11 Students' Involvement: Same HEI to Another HEI

The AIC accommodates students from its home higher education institution to work on research projects. They build on top of existing technologies that AIC is working on. After a while, college students from other universities, who heard of AIC work or visited its website, are accepted as interns. They are given research projects and are closely supervised and mentored by AIC-based professors. Innovations done by different groups of students include putting sensors to detect (1) if the UV light is emitting radiation not intense enough to kill bacteria, then it will signal that the light needs replacement, (2) if the rainwater level in the tank is full so that a valve will open and redirect water to the toilet tanks, and (3) if the water does not have the right acidity or clarity then a valve will open to dispose the water. Students' work immensely contributed to further innovations of WELS and their participation in WELS's deployments provided hands-on learning to the students. Another major contribution of students in technology development and deployment is through training. Some Ateneo college students, from different disciplines, went through training about the assembly and operation of WELS, as part of their government-mandated National Service Training Program (NSTP). In the same manner, Ateneo graduate students, enrolled in Master in Disaster Risk and Resilience (MDRR), did the same thing. Afterwards, they themselves conducted training to the community by demonstrating how to assemble the system and explaining how it operates.

4. RESULT AND DISCUSSION

WELS installation proved to be beneficial in communities whether its purpose is for regular daily use, for emergency or future use. Engagement with the community follows stages which promotes greater appreciation of the technology being transferred and emphasizes mutual benefits in the partnership. The community's water need is addressed, and livelihood alternative is provided, which also ensures the technology's sustainability. Resolutions to challenges encountered in the past installations and the community-recipients' feedback led to further innovation and customization. University students experience hands-on training in their participation during installations. Their experience also allows formulation of innovative ideas to further improve the technology and make it customizable to different contexts. Pre- and post-deployment processes are more collaborative. Collaboration with sponsors and partnership with communities define the success of technology transfer. Community-recipients showed their gratitude and expressed it in different ways. In some areas, Certificates of Appreciation were given to AIC for the effort. In Roxas City, profound gratitude was shown by issuing a resolution recognizing that AIC "has responded generously and swiftly to aid the victims and (AIC's) assistance and donation have eased and improved the plight of our citizentry". A mayor in Iloilo City announced that he would issue a municipal ordinance mandating future government structures to incorporate rainwater-harvesting facility. Some community members shared how having WELS in their community affected their lives. One of the Barangay Captains of Tabuelan in Cebu province said after the post-Yolanda WELS installation, "Salamat po sa ibinigay ninyo, sana dagdagan n'yo pa." (Thank you for what you gave, I hope you would give more). One barangay captain of Jaro District in Iloilo City said in a TV interview that water consumption in their barangay day care center has lessened because of the rainwater harvesting facility installed. One pregnant woman in Cagayan de Oro resettlement area expressed her gratitude after the post-Sendong installation, saying, “Salamat po sa idinonate ninyo dahil hindi na kami magpuputol ng kahoy para magpakulo ng tubig” (Thank you for your donation, we do not have to cut trees to boil water). Deforestation caused flashflood in the province. In the same province, young boys were asked if they know how to install WELS and they answered, “Ay, opo, madali lang po, kayang-kaya namin!” (Yes, it’s easy, we can do it!). Another TV interview of a resident of Coloong (Valenzuela), a flood-prone city, expressed his confidence that they are assured of drinking water inside the community even if their area gets flooded and they cannot go out to buy water. Installation in a hospital in Northern Samar brought a doctor to near tears as she thanked the team saying that “our long wait is over”. Drinking water is a basic need and gaining access to it is seen as an answered prayer.

5. SUMMARY AND RECOMMENDATIONS

Addressing a basic need, like drinking water, necessitates a pre-positioning of a water technology that the community has full understanding of and has great engagement in the process of transfer. Engagement is practiced by making them informed and educated about the technology – its operation, maintenance and repair, its installation, replacement and replication – making them local heroes of the community. Engagement is felt when they are involved in the preparatory and planning stage together with the benefactors – providing and finding local resources and manpower, whatever they can share for the installation to materialize. This signifies ownership of the technology. Engagement is highlighted when they are sought for feedback and informed of adjustments made on the system based on their feedback, making them co-innovators of the technology. This paper presents a model of community engagement that ensures mutual benefit to both university-based-technology providers and community-recipients.We recommend a more active role of higher education institutions in producing research-based technologies that are deployable in communities to address concrete community-wide problems. We further recommend that HEIs aggressively forge industry-partnerships that may result in upscaling of university-developed technologies and, at the same time, support technology-deployments in underserved communities as part of their corporate social responsibility. Networking with HEI’s counterparts in different parts of the country and establishing connections with other service-oriented institutions will also widen awareness of existing problems that may be addressed through its research initiatives and developed technologies. This established network can also facilitate quick communication in time of emergency post-disaster responses. We also recommend that local government units conduct a vulnerability analysis of calamity-prone areas and identify common facilities where critical assets can be installed. In remote communities, water sources can be tested and appropriate interventions be given. LGUs can source funding to enable replication of the system and building of rainwater harvesting facilities to provide safe drinking water.

6 ACKNOWLEDGMENTS

Our gratitude goes Ateneo DReAM Team that sponsored WELS installations and referred some benefactors to AIC. We express our appreciation to the University Research Council (URC) of the Ateneo de Manila University and Coastal Cities at Risk in the Philippines (CCARPH)/International Development Research Center (IDRC) for granting financial support to come up with this paper and to explore further developments. We are indebted to the Ateneo Innovation Center for serving as a hub for WELS development since its initial conceptualization until its actual deployment. Thanks to Mr. Carlos Oppus, AIC Director, and his team of research assistants – Reymond Cao, Kerwin Caballas, Lawrence Ibarrientos, Ashley Tan and Rolland Manlangit. Our most heartfelt gratitude goes to God for answering our prayer to be His instrument in providing clean water to our brothers and sisters who live in remote and disaster-stricken areas. Ad Majorem Dei Gloriam.

REFERENCES

[1]. Born, K. and Laupacis, A. (2012). Public engagement in Ontario’s hospital: Opportunities and challenges. In: *Patient-Centred Care.* Retrieved 04/03/2019 from https://www.longwoods.com/product/download/code/23159

[2]. Brown. J.M. (2007). *Effectiveness of ceramic filtration for drinking water treatment in Cambodia.* University of North Carolina, Chapel Hill, USA. Retrieved 04/03/2019 from https://sswm.info/sites/default/files/reference_attachments/BROWN%202007%20Effectiveness%20of%20Ceramic%20Filtration%20in%20Cambodia.pdf

[3]. Cabacungan, P.M., Tangonan, G.L. & Cabacungan, N.G. (2020). Water-electricity-light-system: technology innovations. *International Journal of Recent Technology and Engineering*. http://ijrte.org/download/volume-8-issue-6/, in press.

[4]. De Gouvello, B., Gerolin, A., Le Nouveau, N. (2014). Rainwater harvesting in urban areas: how can foreign experiences enhance the French approach? *Water Supply*, *569–576.* Retrieved 03/07/2020 from https://doi.org/10.2166/ws.2014.029

[5]. Department of Science and Technology (2014). *Climate of the Philippines.* Retrieved 03/07/2020 from http://bagong.pagasa.dost.gov.ph/information/climate-philippines

[6]. Eerkes-Medrano, D., Leslie, H.A., Quinn, B. (2019). Microplastics in drinking water: A review and assessment. *Current Opinion in Environmental Science and Health*, February 2019. Vol. 7, 69-75. Retrieved 03/08/2020 from https://www.sciencedirect.com/science/article/pii/S2468584418300436

[7]. Franken, L. (2005). The application of ozone technology for public health and industry. In: *Food Safety and Security at Kansas State University*. November 2005. Retrieved 09/20/2019 from http://fss.k-state.edu

[8]. Freese, S.D. and Nozaic, D.J. (2004). Chlorine: Is it really so bad and what are the alternatives? *Water Institute of South Africa*, 30(50). http:///www.wrc.org.za

[9]. Havelaar A.H., De Hollander A.E., Teunis P.F., Evers E.G., Van Kranen, H.J., Versteegh, J.F., Van Koten, J.E., Slob, W. (2000). Balancing the risks and benefits of drinking water disinfection: disability adjusted life-years on the scale. *Environmental Health Perspectives* 108(4): 315-321. Retrieved 09/20/2019 from https://ehp.niehs.nih.gov/doi/10.1289/ehp.00108315

[10]. Kim, Y.K., Han, M.Y., Kabubi, J., Sohn, H.G., and Nguyen, D.C. (2016). Community-based rainwater harvesting (CB-RWH) to supply drinking water in developing countries: lessons learned from case studies in Africa and Asia. *Water Science & Technology: Water Supply* (2016). Retrieved 03/08/2020 from https://pdfs.semanticscholar.org/a7ba/36f8f055bcfc53de4a2e722b66269030d10e.pdf?_ga=2.18286457.1380781319.1583725704-900793807.1583725704

[11]. Medina, B.O. (2019), Community engagement of state universities and colleges in the Philippines: Towards socially and culturally responsible research and extension initiatives. *International Journal of Advanced Research and Publications*, 3(4), 2019. Retrieved 03/08/2020 from http://www.ijarp.org/published-research-papers/apr2019/Community-Engagement-Of-State-Universities-And-Colleges-In-The-Philippines-Towards-Socially-And-Culturally-Responsible-Research-And-Extension-Initiatives.pdf

[12]. Nasronudin, Juniastuti, Oktamia, R. H., and Lusida, M. I. Infectious diseases after tsunami Aceh (Indonesia) experience. *Journal of Disaster Research*, 2012, 7(6): 754-758 . Retrieved 09/21/2019 from https://www.fujipress.jp/jdr/dr/dsstr000700060754/?highlight=%20clean%20water%20disaster

[13]. Philippine Statistics Authority (2019) *Most Filipino families have access to improved source of drinking water (Results from the 2017 annual poverty indicators survey (APIS) and water quality testing module).* Retrieved 03/08/2020 from http://www.psa.gov.ph/content/most-filipino-families-have-access-improved-source-drinking-water-results-2017-annual

[14]. Pieterse, M.J. (1988) The potential health risk of trihalomethanes in drinking water: a perspective, *S. Afr. J. Sci.* 84:166-170. Retrieved 09/21/2019 from http://www.wrc.org.za/wp-content/uploads/mdocs/2808.pdf

[15]. Rainwater Harvesting Facility Act, HB 4340, 2019. *Press and public affairs bureau.* House of Representatives, 18th congress, first regular session. 14 February 2019. Retrieved 03/08/2020 from http://www.congress.gov.ph/press/details.php?pressid=11303

[16]. Sobsey, M.D. (1989). Inactivation of health-related microorganisms in water by disinfection processes. *Water Sci. Technol.*, 21(179). Retrieved 09/21/2019 from http://www.wrc.org.za

[17]. Song, J.M., Han, M.Y., Kim, T., and Song, J.E., (2009). Rainwater harvesting as a sustainable water supply option in Banda Aceh. *Desalination*, 248(1-3), 233-240 (2009). Retrieved 03/08/2020 from https://www.sciencedirect.com/science/article/pii/S0011916409005906

[18]. Tacio, H.D. (2018). When water caused diseases and deaths. *Business Mirror*, March 8, 2018. Retrieved 03/08/2020 from https://www.businessmirror.com.ph/2018/03/08/when-water-causes-diseases-and-deaths

[19]. World Health Organization. (2019). *Water shortage in the Philippines threatens sustainable development and health.* Retrieved 03/08/2020 from https://www.who.int/philippines/news/feature-stories/detail/water-shortage-in-the-philippines-threatens-sustainable-development-and-health

AUTHOR PROFILE

Mr. Paul M. Cabacungan received his M.S. degree in Electronics Engineering from Ateneo de Manila University in 2009. He is a senior research engineer and the operations manager of Ateneo Innovation Center. He is primarily responsible for organizing the different research groups of the center. His research initiatives are in the field of innovative solutions for community disaster resilience and low-cost medical devices. He has installed more than 140 units of solar clean water systems nationwide, fabricated low-cost smart phototherapy units and indoor aquaponics. He advocates for free transfer of innovative technologies to empower communities.