iSTEP 2012: Waste Monitoring and Water Monitoring and Management at Ashesi University College in Ghana

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Waste monitoring and water monitoring and management at Ashesi University College in Ghana

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ABSTRACT

The TechBridgeWorld innovative Student Technology ExPerience (iSTEP) internship program provides Carnegie Mellon University students and recent graduates with the opportunity to work in a multidisciplinary and globally distributed team to develop needs-based technology solutions in collaboration with developing communities. The iSTEP 2012 internship addressed two environmental sustainability challenges at the community partner location, Ashesi University College(Ashesi) in Berekuso, Ghana. This report provides a detailed account of the 2012 internship covering logistics, team preparation, needs assessment, solution design, evaluation, recommendations for Ashesi, and reflections on the internship experience. For the two field research projects: water monitoring and management and waste monitoring, the initial focus was on understanding the local context through an in-depth needs assessment. The iSTEP team developed a community awareness plan in combination with a data transfer system that utilized a combination of sensor and computing technology to monitor and better manage waste production and water resources on the Ashesi campus.

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ACKNOWLEDGEMENTS

The iSTEP 2012 team would like to thank all of the people who enabled us to work on this incredible internship experience. This work would not have been possible without the collaboration of our Ashesi University College (Ashesi) student teammates Sonia Adda, Juliana Botsio, Selase Attah Kwamuar, Diana Dayaka Osei, Maame Abena O. Owusu-Acheaw, Nii Adjetey Sowah, and Kanba Daniel Tapang. We also thank the advisors from Ashesi, most notably, Raymond Agbesi, Nathan Amanquah, Casper Annie, Patrick Awuah, Ebenezer Gwumah, Ayorkor Korsah, and Astrid Larssen who added valuable guidance and insight to this work and facilitated the progress of the projects. To the entire faculty, staff and students of Ashesi, thank you for participating in our surveys and focus groups. We are also grateful to the iSTEP 2012 advisors Hatem Alismail, April Conkey, David Dausey, KG Karthikeyan, Chris Labash, Roberto Ponce Lopez and Matt Richards. Additionally, the work of previous iSTEP teams has been invaluable to the success of this year's projects. We thank them for their contributions to the field of information and communication technologies for development; we learned a great deal from their experiences in the field. Thanks are also due to the Carnegie Mellon University community at large. We also thank donors to our 100@100 annual fundraising campaign and other general TechBridgeWorld sponsors who support our iSTEP program. Without such support, these experiences and projects would not be possible. Finally, we would like to extend our hands in partnership and our hearts in gratitude for the opportunity to work with the greater Berekuso community in Ghana, and contribute to the body of knowledge on water and waste monitoring and management.

EXECUTIVE SUMMARY

Launched by TechBridgeWorld (TBW) in 2009, the innovative Student Technology ExPerience (iSTEP) provides Carnegie Mellon students and recent graduates real-world experience and the opportunity to develop needs-based solutions with a community partner. The iSTEP 2012 collaborating partner was Ashesi University College (Ashesi) located in a peri-urban region of Ghana. Ashesi had recently moved from a temporary location in Accra to its permanent campus in Berekuso in the Eastern Region of Ghana. The move and Ashesi's focus on resource management and environmental sustainability precipitated project identification for iSTEP 2012. Six team members from Carnegie Mellon (CMU) and seven team members from Ashesi, with guidance from TBW and Ashesi faculty and staff, undertook environmental sustainability projects: (1) waste monitoring and (2) water monitoring and management. The goal was to examine and design solutions to meet the water monitoring and management and waste monitoring needs of Ashesi.

Prior to the 10-week summer internship, the CMU team spent 16 weeks during the spring academic semester in preparation via. Through the courses the students learned how to work together as a team, did background research on Ghana, the project partner location and project areas, prepared for their individual roles as well as performed preliminary needs assessment.

Ashesi is a relatively small campus which currently consumes water and generates waste from approximately 600 students, facility and staff. As Ashesi grows, resource management will become an increasingly important asset for cost-saving and limiting the environmental impacts of Ashesi on neighboring villages—an important goal of Ashesi's leadership. Ashesi's water comes from a borehole located near campus and rainwater. They have their own water treatment system. Ashesi was interested in a water monitoring and management plan for this framework. Similarly, Ashesi did not have a waste policy or framework in place. Ashesi had a unified waste collection process: waste collected from bins was aggregated at a central location and disposed of by a third party contractor. Ashesi was interested in waste monitoring to determine the amount of waste generated on campus, including the types of waste being generated as well as the amount of each type, and to identify third party waste recycling contractors. To this end needs assessment was carried out.

The needs assessment was designed within the framework of participatory research where solution design is an iterative process between end-users and the research team. A mix of qualitative surveys, interviews and focus groups along with raw data collection ranging from water consumption patterns to waste source audits were used, whose purpose was to both assess what users saw as needs and what the data indicated were areas to be addressed. Campus wide surveys helped the team best understand the general "landscape", e.g. aggregate preferences towards conservation tactics, core uses of water and types of waste generation, and how knowledgeable students and staff were in regards to each system. Stakeholder interviews were important to understand what the priorities of each project were for the people who would actually be carrying out the technical solutions in the future, while expert interviews mostly illuminated core system details and possible points for intervention. Focus groups offered a more detailed vantage point of how students and faculty were likely to actually change behavior. The groups gave the team insights into how elastic consumption habits were and thus how effective particular awareness strategies would be. For the water project daily water consumption was collected while waste audits and data on plastic bottles use was collected for the waste project.

For the water project virtually all stakeholders indicated that the current lack of data collection made appropriate policy making very difficult. A critical mass of data for campus building-level consumption and water supply sourcing (borehole, purchased or rainwater) was needed to accurately understand

water solutions. For example, should Ashesi purchase machines that reduce water consumption in the kitchen or low-flow shower heads in the dormitories? How much rainwater should operations management anticipate using during the rainy season? Answering such questions presuppose a baseline understanding of usage patterns and water consumption data. Furthermore, water monitoring and management system needed to have low managerial oversight costs—i.e. data, if manually input, must be intuitive, consistent, and insure accuracy. Rainwater at Ashesi could either serve as a primary water source during the rainy season or as a back-up in the event the borehole fails. Data on storage capacity would enable operations staff to use rainwater more effectively while still ensuring some level of storage capacity in the event of borehole failure.

The needs evaluation of Ashesi's waste monitoring differed from the water project. First, from stakeholder interviews emerged a goal to identify the market opportunities to begin recycling efforts. There were few recycling centers in Ghana and virtually all were located in Accra or in Tema. Because of the distance to these centers and the poor quality of the road to Ashesi the college had not been able to get anyone to pick up recyclables. Therefore, waste data collection was needed to understand how much recyclable material Ashesi generated and given the amount, the best means of getting this waste to recycling centers was not known. Moreover, data on the community's wiliness to segregate trash was needed.

To improve data collection on water usage and waste generation, a multi component system was developed, which included a centralized database to store the information, a web browser interface to search and visualize the data, and multiple input systems for both manual and automatic data entry into the system. For the water system the solution deployed several digital water meters that automatically populated the database along with an SMS and phone application backend-system that allowed individuals to manually collect and store data from analog meter readings. To increase accuracy, the system had several anomaly detection features. The solution was demand-driven, with an intuitive web-based user interface that allowed users to easily recall and analyze water data. Additionally, the content management system (CMS) backbone was open-sourced and designed for scale as Ashesi grows or decides to purchase additional sensors for more granular data. A prototype for the water solution was implemented.

Once the composition of Ashesi's waste was understood it became apparent that any long-term strategy for waste reduction and reuse would demand a solution for organic waste. (Two-thirds of all waste on campus was organic.) So, the waste team analyzed composting technologies and market opportunities for Ashesi to provide organic fertilizer to surrounding farmers. Data collection was important. Identifying the most appropriate technology required both an understanding of the spectrum of monitoring technology available and the practical application for such technologies both currently and in the future. Strategies were introduced for creating awareness as well as a pilot to evaluate the amount of recyclables that could actually be segregated on campus.

Finally, the team addressed long-term planning and future awareness campaigns through a strategic document that identified and tailored best-practices globally to Ashesi's current and future needs. The water project implementation addressed the need to easily collect and use water data with a data collection system that was simple, comprehensive and scalable for future use. A particular type of sensor and network of sensors were recommended. The project short- and medium-term aim was to ensure the ability for data analysis that dictated best practices and policy recommendations. It allowed operations and administrative stakeholders to make better decisions, but the project deliverables themselves offered few specific policy recommendations. The waste project, on the other hand, was highly influenced by external forces—particularly the market for recyclables—and internal consumption patterns—how willing students were to actually recycle. While the water project created a specific technical solution designed for scale, the waste project surveyed numerous technical options (from large scale composters to weight scales), with weight and volume prototypes, but left the actual long-term monitoring technology decision in the hands of Ashesi stakeholders. The waste team not only offered concrete policy recommendations for waste reduction, they also developed a pilot project to analyze recycling, reduction, and source segregation efforts.

In summary, over the course of the internship, the teams completed comprehensive qualitative needs assessment coupled with raw data collection. Based on this information and in collaboration with Ashesi, they developed and evaluated a data management system that employed SMS-to-database and sensor technologies to transfer information. The information collected and transferred to the system would then help monitor the waste and monitor and manage the water on campus. The team plans to release the technical development information open source so it can be replicable at another campus or location of a varying size. The research is also meant to be utilized by Ashesi in the future if the campus should grow in population or consumption level.

Although both projects are distinct, the waste and water challenges on campus lay in tangent with one another. For instance, if students were to drink more tap water and less bottled or sachet water, then the amount of waste would decrease. However in that case, the water supply would need to be closely monitored to ensure enough supply of clean, drinking water on campus. An awareness campaign would also have to be employed to inform the students about drinking more tap water from the campus, thereby creating less bottle and sachet waste. Just as waste and water go hand in hand, the team saw fit that the solutions must work together as well. The management plan for both projects followed similar models. Both plans included needs assessment, technical development, testing, evaluation and implementation. Furthermore, the needs assessment relied on surveys, focus groups and raw data. Much of this information was collected for both projects at the same time, whether within the same survey paper or within the same focus group. The technical solutions were developed for use by both projects and only differed slightly depending on the object involved (i.e. waste bin vs. water meter). Finally the dissemination strategy included web 2.0 and the completion of this technical report, all of which recaps both projects equally.

1. INTRODUCTION

The iSTEP 2012 internship sought to address environmental sustainability challenges at Ashesi University College (Ashesi) in Berekuso, Ghana. The innovative Student Technology ExPerience (iSTEP) is a summer research internship opportunity offered by the TechBridgeWorld (TBW) research group at Carnegie Mellon University (CMU). TBW develops and field tests sustainable technology solutions to meet development needs around the world. Through the iSTEP program TBW strives to extend this type of field research experience to students at CMU. This year's iSTEP team consisted of six CMU students and recent graduates from various disciplines in collaboration with a team of seven Ashesi students and recent graduates. Together with guidance from TBW and Ashesi faculty and staff, the teams worked on two environmental sustainability projects: (1) a waste monitoring project and (2) a water monitoring and management project.

Ashesi's growth and its new location outside Accra have introduced new stakeholders to its resource monitoring and management priorities. Its new home in the village of Berekuso is home to significantly fewer people than a large city like Accra. Thus, the presence of Ashesi brings greater consumption of community water resources and increases waste production. Moreover, as its population rises, the school will also be accountable for its rising impact on the local community of Berekuso. Ashesi is committed to environmental sustainability and resource management. Ashesi plans on leveraging its international partnerships to create better monitoring and management of its resources. The iSTEP 2012 partnership and projects are integral parts of this plan. Ashesi seeks to improve the systems that are currently used to meet its water, waste disposal and energy needs by implementing measurable and quantifiable evaluation of those resources. Monitoring waste production and water usage has the potential to inform the Ashesi community about its resource consumption and will serve as a tool to facilitate behavioral changes toward efficiency and conservation.

Rapid population growth, urbanization, and increased resource extraction throughout West Africa has made appropriate water and waste management a lynchpin of sustainable development. Information and communication technologies (ICT) could be used to reduce the impact of waste and limited water resources by improving environment monitoring and data collection. While monitoring cannot prevent waste accumulation or replace water conservation policies, it can help users adopt best practices, identify temporal and spatial variability in consumption trends, and mitigate the impact of extreme events (such as drought). Monitoring informs decision making by identifying major sources of waste generation—such organic composition or recyclables—and water consumption—domestic, industrial or commercial use—which in turn suggest appropriate conservation efforts. Monitoring is also particularly important in developing communities with access to rainwater. Rainwater harvesting is low-cost and a renewable resource, but also exposes consumers to seasonal volatility. Effective rainwater harvesting is best a complement to traditional water sources (such as boreholes) and most valuable when rainwater collection and consumption trends can be normalized and predicted. Doing so requires reliable and granular data collection. Similarly, there are numerous best-practices for waste reduction, reuse and recycling but accurate data for source segregation is often a necessary precondition. It is important to consider both technical and non-technical solutions to meet the water monitoring and management and waste monitoring needs of Ashesi University College in Berekuso, Ghana. Ashesi is a relatively small campus, located in a peri-urban eastern region of Ghana, whose students, faculty and staff number slightly more than 600. Ashesi recently moved to this permanent campus and is now faced with overseeing its own water resources and waste. As Ashesi grows, resource management will become an increasingly important responsibility for cost-saving and limiting the environmental impacts of Ashesi on neighboring villages—an important goal of Ashesi's leadership. Ashesi's water and waste needs represent a specific example of a common scenario in adapting resource management in a peri-urban region in Ghana. The aims of the iSTEP 2012 projects were to develop and implement solutions that match the goals of Ashesi. This report details how that was achieved.

The next section covers background information about who was involved with the projects and how the iSTEP and TBW teams prepared for them. Subsequent sections provide an extensive description of the iSTEP 2012 projects, then the needs assessment for those projects, followed by the overall solution design, then the evaluation of the solutions. Next, recommendations and long term planning for the sustainability of the projects is presented. Prior to the closing conclusions, the students provide personal reflections on their experience.

2. BACKGROUND

2.1 TechBridgeWorld

Most developing communities have not benefited from technological advancements to date. In cases where technology has benefited these communities, the benefits are often highly asymmetric. Thus, technology has contributed to divides between developed and developing communities that further impede the development process. While many organizations continue to focus on enabling sustainable development, very few organizations have studied the role of technology in this process. TechBridgeWorld at Carnegie Mellon University is spearheading the innovation and implementation of technological solutions relevant and accessible to developing communities; using technology to build bridges rather than exacerbate divides [1]. Designing and implementing technology that can enhance suitable and sustainable development presents unique challenges in creativity and resourcefulness. Work in this area is often referred to as Information and Communication Technology for Development (ICTD), and there are a growing number of academics, development practitioners, and businesses focusing on this relatively new field.

TechBridgeWorld is a research group, based in the Robotics Institute at Carnegie Mellon University, that develops and field tests sustainable technology solutions to meet development needs around the world. Founded in 2004 by Robotics Associate Research Professor Dr. M. Bernardine Dias, TechBridgeWorld pioneers research in the field of ICTD. Since 2004 TechBridgeWorld has been collaborating with partners in developing communities while enhancing the role of technology globally. As their motto states, TechBridgeWorld seeks to develop, "technology with a global heart." TechBridgeWorld creates accessible and relevant technology by focusing on two main principles: sharing expertise to create innovative and locally suitable solutions, and empowering local populations to create sustainable solutions. TechBridgeWorld works closely with the community to address long-term challenges and to develop sustainable solutions. Through the knowledge and creativity of Carnegie Mellon faculty, staff, and students, TechBridgeWorld utilizes computing technology expertise to help realize the community's vision of development.

ICTD field research is a tremendous opportunity to learn firsthand about a partner community. There are many challenges that come with field work, especially in places where electricity, internet connection, and clean water may be in short supply. By trying to live among and work with people in the partner community, TechBridgeWorld researchers seek to gain a greater understanding of daily challenges in peoples' lives. All of TechBridgeWorld's core team members have engaged in field work experiences and can offer valuable insight to students preparing to conduct projects in developing community settings.

2.2 iSTEP Internship Program

The iSTEP internship program is designed to empower the next generation of leaders to explore challenges of ICTD field work and how technology can make a positive impact. Launched by TechBridgeWorld in 2009, iSTEP ("innovative Student Technology ExPerience") gives CMU students and recent graduates real-world experience in the ICTD sector, as well as the opportunity to develop needs-based solutions in collaboration with developing communities. iSTEP is a rigorous, hands-on, international research experience. The internship is designed so that the team works closely with local partners in developing communities and contributes their expertise by inventing new tools and customizing existing technology. The program is open to graduate, undergraduate, and recent alumni of CMU's Pittsburgh and Doha campuses. Students undergo an interview process in the fall semester and selected interns prepare for 16 weeks for their summer work in the spring semester through coursework for credit. The spring coursework is followed by a 10-week paid internship during CMU's summer break. In addition to the project deliverables, the iSTEP interns conduct a final presentation for local partners and produce a final report in collaboration with the TechBridgeWorld team.

In some iSTEP collaborations TechBridgeWorld's partners engage local university students working alongside the interns from CMU with the intent of local students helping to sustain the projects in the longer term. Past iSTEP collaborations involved partnerships in Tanzania (2009), Bangladesh (2010), and Uruguay (2010). The iSTEP 2012 collaboration in Ghana resulted from past partnerships between TechBridgeWorld and Ashesi University College. During iSTEP 2012 Ashesi interns were mentored and supervised by their own faculty while CMU interns were mentored and supervised by TechBridgeWorld faculty and staff. A TechBridgeWorld faculty member also worked with the team and partners on site in Ghana for two weeks during the iSTEP internship.

2.3 iSTEP 2012 Partner Community

2.3.1 Ghana Overview

Ghana is a West African nation bordered by Cote d'Ivoire, Burkina Faso, and Togo. The country is divided into ten regions (Figure 1): Upper West, Upper East, Northern, Brong-Ahafo, Ashanti, Western, Central, Greater Accra, the Volta region and Eastern (where Ashesi is located). Ghana has a population of 24 million with a low population density of 88 people per square mile. At 92,100 square miles, the country is similarly sized to the U.S. state of Washington. The coastal region of Accra, Cape Coast and Takoradi are at sea level while the rest of the country gradually rises in elevation towards the North, reaching 914 meters near the city of Tamale [2]. Like most subequatorial regions, Ghana's climate has distinct hot summer seasons, dry winters and rainy seasons. Specifically, the iSTEP internship took place during the rainy season.

Figure 1. Regions of Ghana (Sterk, 1977)

The vast majority of Ghana is rural, however roughly half the population lives in cities. The largest city and capital is Accra located on the coast and about 20 miles from Ashesi's Berekuso campus. While the majority of Ghanaians live in the southern triangle of Accra, Kumasi, and Takoradi, rural villages are scattered as far north as the Burkina Faso border. The northern city of Tamale is a major trade route into central Africa. Rapid population growth, urbanization, and increased resource extraction throughout West Africa has made appropriate water and waste management a lynchpin of sustainable development.

Solid waste, especially urban solid waste creates large environmental challenges in Africa. The generation of waste increased drastically in the last two decades. The key challenges posed by growing cities and population are waste generation, composition, storage, collection and transport, disposal and the awareness generation.

2.3.2 Ashesi University College

Ashesi is a coeducational institution founded in 2002 in the Labone district of Accra, Ghana. It focuses on technology and developing future African leaders from liberal arts pedagogy. In many aspects, Ashesi reflects Ghana's historically innovative and technical outlook. Ashesi's mission statement expresses that it "fosters critical thinking, problem solving, and a concern for others." [3] Since its inception, Ashesi has grown from graduating 30 students in 2005 to 70 in 2012. Ashesi founder and current president Patrick Awuah, a native Ghanaian, is ranked as one of the nation's top ten CEOs. He left his successful software engineering career in the U.S. in order to return to Ghana and make an impact on ethical leadership and innovation in Africa [4]. As part of its large commitment to ethics, Ashesi students sign an honor pledge and engage in a student-accountability code that transfers their ethical work beyond graduation and into the workplace. According to Ishac Diwan from Harvard's Center for International Development, "Ashesi's presence in Africa is a strategic one because Africa is in dire need of leaders who are empathic, critical thinking and want to make a difference; the very core of the Ashesi mission" [4]. Likewise the former World Bank, International Finance Corporation (IFC) Director, Peter Woicke, called Ashesi, "An accelerator for change" as it will guarantee future generations of civic leaders in this region and the rest of the world [4].

In 2010 Ashesi relocated its campus from an urban site in Accra to the more rural Akuapim Hills of Berekuso. Its new location has reformed the university by focusing on advancements in environmental sustainability. Ashesi aims to accommodate up to 2,000 students and is currently able enroll 600 students, while providing living accommodations to 320 students. 11 African countries are represented in the current student population [3]. Universities with strong liberal arts and technical training, such as Ashesi, are rare and deeply needed in Sub-Saharan Africa where only 5 percent of the population attends college [5].

Ashesi's growth and its new location outside Accra have introduced new stakeholders to its resource monitoring and management priorities. Its new home in the village of Berekuso is home to significantly fewer people than a large city like Accra. Thus, the presence of Ashesi brings greater consumption of community water resources and increases waste production. Moreover, as its population rises, the school will also be accountable for its rising impact on the local community of Berekuso.

Ashesi is committed to environmental sustainability and resource management. Ashesi plans on leveraging its international partnerships to create better monitoring and management of its resources. The iSTEP 2012 partnership and projects are integral parts of this plan. Ashesi seeks to improve the systems that are currently used to meet its water, waste disposal and energy needs by implementing measurable and quantifiable evaluation of those resources. Monitoring waste production and water usage has the potential to inform the Ashesi community about its resource consumption and will serve as a tool to facilitate behavioral changes toward efficiency and conservation. The focus of the environmental policy being developed by Ashesi is to ensure that the environment is clean and litter-free at all times as well as self-sufficient in supplying treated water. Based on the environmental interests at Ashesi's new campus, Ashesi and TechBridgeWorld identified two research projects for the summer 2012 collaboration:

- Water Monitoring and Management Project
- Waste Monitoring Project

There has been a strong partnership between Ashesi and TechBridgeWorld for several years. Ashesi and TechBridgeWorld collaborated on two occasions prior to iSTEP 2012. In the summer of 2006, Ashesi offered the first college robotics course in Ghana (Figure 2) as a combined effort with CMU through TechBridgeWorld [6]. A Ghanaian graduate student from CMU's Robotics Institute, Ayorkor Korsah, and Ashesi faculty member Nathan Amanquah co-taught the course with CMU Robotics faculty M. Bernardine Dias and Brett Browning. Robots were built using LEGO kits and programmed in Interactive C. The pilot course emphasized the use of advanced technologies combined with local understanding and resources to have the greatest possible local impact. Students also presented their individual projects during a poster session. The university planned to teach more advanced courses in robotics and artificial intelligence based on the success of this course [6], and now offers it as a computer science elective when there is student interest [7]. Another collaboration occurred in 2008, when two CMU graduate students conducted a summer program with TechBridgeWorld and the Technology Consulting in the Global Community program. They lived and worked at Ashesi's Accra campus, helping Ashesi to define the requirements for an automated student records management system. CMU students Kathryn Dickens and Adrienne White collaborated with Ashesi colleagues to research and evaluate open source and commercial alternatives, choose a system to adopt, define an implementation plan, and create training materials. In 2012 through iSTEP, CMU and Ashesi combined forces once again with the help of Ayorkor Korsah, now a CMU Robotics Ph.D. alumna and an Ashesi faculty member in the computer science department.

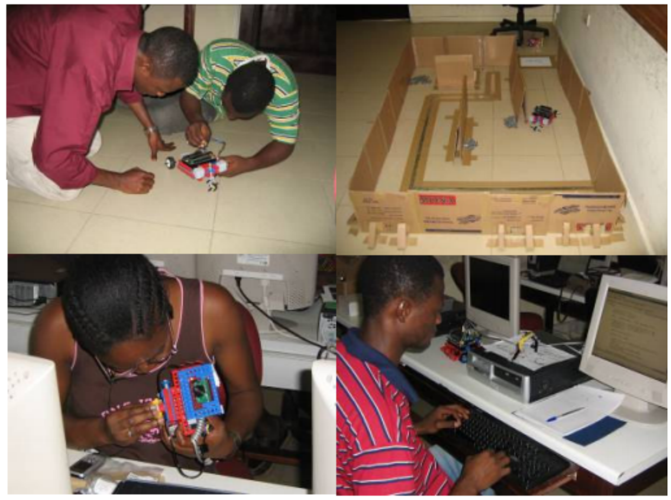


Figure 2. Students in Ashesi's first robotics course (Mills-Tettey, 2007)

2.4 The iSTEP 2012 Team

The iSTEP 2012 team consists of five students and recent graduates from CMU and seven students and recent graduates from Ashesi. The teams were advised by faculty and staff from TechBridgeWorld and Ashesi.

2.4.1 iSTEP 2012 Interns

Sonia Awedoba Adda is a recent graduate of Ashesi University College with a B.Sc. in Business Administration. She previously volunteered as community service personnel at Ada where her team introduced a self-sustenance program by starting a farm for Elavanyo Basic School. She also worked on a water conservation project that proposed ways to recycle water. She loves math and in her free time enjoys swimming and sharing jokes with friends.

Sonia's primary assignment during the iSTEP 2012 internship was Needs Assessment and Evaluation.

Scott Andes is pursuing a master's degree in Public Policy and Management at Carnegie Mellon University's Heinz College where he focuses on Economic Development and Technology. Scott previously worked as a research analyst at the Information Technology and Innovation Foundation in Washington DC. His research interests include economic competitiveness, ICTD, agriculture policy and innovation policy. Scott received his bachelor's degree in Government from the London School of Economics.
Scott was the project manager for the Water Monitoring and Management project.

Juliana Esi Tanoa Botsio recently completed her studies at Ashesi University College with a degree in Business Administration. During her time at Ashesi, she served as a member of the Welfare and Academic Committees. She was also the financial secretary of the Ashesi Model United Nations and currently serves as an advisor. Juliana previously worked as a dental surgeon assistant, writing tutor and telemarketer, to name just a few. When not working or at school, Juliana loves to listen to music.
Juliana's primary assignment during the iSTEP 2012 internship was Community Awareness.

Corinne Clinch will be a junior at Carnegie Mellon University in Fall 2012. She is double majoring in Biomedical Engineering and Civil and Environmental Engineering but also dabbles in computer science and psychology. She grew up in Hampton, Virginia where she participated in research at NASA and ACEnT Laboratories. On campus, Corinne is involved with the Explorers Club and has served as a teaching assistant for a Python programming course. In her free time, she enjoys adventure sports, travelling, dancing, and meeting new people.
Corinne was the team's Software Developer. She supported her teammates with technology development for both iSTEP 2012 projects.

Selase Attah Kwamuar is an incoming senior at Ashesi University College majoring in Computer Science. In addition to school, Selase works as a web developer and a flash animator at BusinessGhana Ltd. He has worked on several web applications for organizations such as The Old Achimotan Association, Franklyn Medicals, etc. He also worked on several adobe flash projects for Emirates Airlines. Selase had originally wanted to be a jewellery designer. However, in an attempt to discover himself he tried programming as a hobby and enjoyed it. Now, he finds himself programming by default, though it can be challenging and tedious at times.
Selase's primary assignment during the iSTEP 2012 internship was Data Gathering and inputting sensor data into the database.

Julie Mallis recently graduated from Carnegie Mellon University with a Bachelor of Humanities and Arts (BHA) degree, concentrating in Art and Anthropology. She recently worked on a project to connect part of the Somali Diaspora from Pittsburgh to the Netherlands using art and GigaPan cameras, while working with refugee populations. She co-founded the Magic Organs Zine Company and Artist Collective and has shown work in various galleries and publications. She served on Carnegie Mellon's School of Art Student Advisory Council for three years.
Julie was the team's Dissemination Coordinator based in Pittsburgh, US. She led the team's dissemination efforts for the iSTEP 2012 internship.

Diana Dayaka Osei is pursuing a B.Sc. in Computer Science at Ashesi University College. In her junior year, she took a course in Human Computer Interaction and gave a presentation on what the developed world can learn from how Africans use technology, which her classmates found remarkable. That same year, she was one of five Ashesi students chosen to work with the Google Africa User Experience team, who visited Ghana to evaluate the impact of Google Trader in Ghana and to investigate how Ghanaian businesses go online. Her undergraduate thesis was on enabling Ghanaian sign language instruction with technology. She aspires to be an advocate for Women in ICT and a social entrepreneur. When she is not interacting with people, you will find her writing or reading.
During the 2012 iSTEP internship, Diana's primary assignment was Dissemination. She also served as the overall Ashesi Team Leader.

Sandeep Reddy Munnangi is a Public Policy and Management graduate student at Carnegie Mellon University's Heinz College where he is involved with the International Development Group and Heinz Consulting Club. Sandeep received his bachelor's degree from Indian Institute of Technology in Electronics and Communication Engineering. He then worked as a Consultant in Government Services and Advisory Practices at Ernst & Young. Sandeep's interests are in technology for development and governance and financial management reforms.
Sandeep was the project manager for the Waste Monitoring project.

Maame Abena O. Owusu-Acheaw a recent graduate of Ashesi University College with a Bachelor's degree in Business Administration and a minor in Computer Science. Maame has an interest in promoting the welfare of children and has recently co-founded and managed the Readworm Library Project. On campus, she has served in various capacities including residential assistant for her hall, a career peer advisor for her four years as a student, and is currently an advisor to the Readworm club. Her most recent research was related to finding how best property management practices can be incorporated in the management of Ghanaian urban roads. In her free time, Maame spends time writing (especially poems), volunteering with children, making beads, decorating and designing.
Maame Abena's primary assignment during the iSTEP 2012 internship was Longer Term Strategy.

Ronnell Perry is pursuing a master's degree in Public Policy and Management at Carnegie Mellon University's Heinz College. Reflected in his role as Community Outreach Coordinator for the International Development Group at Heinz College, Ronnell is very passionate about development and capacitating in communities of need. In 2009, he volunteered in a farming community in Paraguay and an indigenous reserve in Costa Rica through the Peace Corps. Ronnell earned his bachelor's degree at Dillard University in international business and Spanish.

Ronnell was the team's Assessment Coordinator and CMU Team Leader. He led the team's needs assessment and evaluation efforts for the iSTEP 2012 projects.

Nii Adjetey Sowah recently completed his undergraduate study at Ashesi University College in the Computer Science program. He was exposed to a wide variety of concepts in the field, some of which included computer hardware design, the development and design of embedded systems, compiler/interpreter development, database management and design, software engineering and design, and robotics. In 2010, Adjetey volunteered to teach junior high school students at a local community school. He enjoys reading Japanese manga (comic books) and street art in his spare time.

Adjetey's primary responsibility during the iSTEP 2012 internship was Sensing.

Kanba Daniel Tapang is a Faculty Intern at Ashesi University College's Computer Science department, where he recently graduated from. Kanba hails from Bunkpurugu in the Northern Region of Ghana. Since he was young, he has been a fan of science, computers, video games and soccer. During his free time, Kanba is involved with outreach work at his church.

Kanba's primary assignment during the iSTEP2012 internship was Visualization.

2.4.2 TechBridgeWorld Advisors

M. Bernardine Dias, Founder and Director, is an Associate Research Professor in the Robotics Institute at Carnegie Mellon University's School of Computer Science. Her research expertise are in technology for developing communities, assistive technology, and autonomous team coordination. Dr. Dias is a native of Sri Lanka. Her career goal is innovating means of developing and disseminating suitable and sustainable technology for empowering underserved communities. She is a strong supporter and mentor for women in science and technology.

Yonina Cooper, Associate Director, is an Associate Teaching Professor in the School of Computer Science at Carnegie Mellon University in Qatar. She co-teaches the Technology and Global Development course at Carnegie Mellon Qatar with M. Bernardine Dias and is a Qatar faculty advisor for the iSTEP program. Her research interests are in the areas of education and technology: ICT in education in developing countries, identifying technology that is accessible and relevant to the needs of a developing community, and adapting Alice (software) to be culturally relevant for Middle East schools.

M. Beatrice (Bea) Dias, Postdoctoral Associate, is based in the Robotics Institute at Carnegie Mellon University's School of Computer Science. She is collaborating with the TechBridgeWorld team to assess different projects in ICTD, with a focus on literacy tools designed for developing communities across the globe. Beatrice conducted three of her Ph.D. research studies in collaboration with TechBridgeWorld to understand the effect of technology in developing communities across the globe. The genesis of this research was her experience as a participant in TechBridgeWorld's inaugural iSTEP internship program in 2009 in Dar es Salaam, Tanzania.

Sarah M. Belousov, Project Manager, is based in the Robotics Institute at Carnegie Mellon University's School of Computer Science. Her primary responsibilities involve supporting TechBridgeWorld's activities through partnerships, fundraising, field work, and program planning. She earned her M.S. in Public Policy and Management at Carnegie Mellon's Heinz College, and her B.A. at Johns Hopkins University, majoring in International Studies and minoring in French. She also studied at l'Institut d'Études Politiques in Paris. Prior to joining TechBridgeWorld, Ms. Belousov worked at the World Affairs Council of Pittsburgh and participated with Leadership Pittsburgh's Leadership Development Initiative.

Ermine A. Teves, Project Assistant, graduated from Carnegie Mellon University in May of 2008 with a B.S. in Business Administration with a concentration in Marketing. She is currently pursuing a master's degree in Public Policy and Management at Carnegie Mellon University's Heinz College with a concentration in Social Innovation. She became interested in technology for sustainable development while interning for TechBridgeWorld during her undergraduate studies. In summer 2008, she spent 10 weeks in Bangalore, India interning with Microsoft Research India and the Mathru School for the Blind on the Braille Writing Tutor project through TechBridgeWorld. Shortly after completing the internship, Ermine joined the TechBridgeWorld team full time and her responsibilities include expanding TechBridgeWorld programs, marketing, and fundraising efforts. Ermine is a native of the Philippines and hopes to facilitate future TechBridgeWorld projects in her home country.

M. Freddie Dias, Research Engineer, is based in the Robotics Institute at Carnegie Mellon University's School of Computer Science. He assists with robotics research in the Field Robotics Center, supporting projects related to multi-robot coordination. He also serves as a technical consultant for projects related to technology and development under the TechBridgeWorld initiative. His work in both categories bridges Carnegie Mellon University's campuses in Doha and Pittsburgh. Originally from Sri Lanka, he graduated from Hamilton College in New York with a double major in physics and computer science.

Balajee Kannan, Technical Consultant, is a Project Scientist in the Field Robotics Center at the Robotics Institute at Carnegie Mellon University. His research experience lies in the area of multi-robot systems, specifically in fault-tolerance for multi-robot systems, adjustable autonomy, multi-robot coordination and execution, and AI for assistive technology. His career vision is to use technology to make next-generation cities accessible to all. A native of India, he holds a BE in Computer Engineering from Madras University in India and a M.S. and PhD in Computer Science from the University of Tennessee, Knoxville.

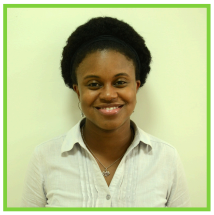
2.4.3 Ashesi University College Advisors[1]

Nathan Amanquah has also worked on employing middleware techniques for location dependent and context aware delivery of services, and on service discovery protocols. He has developed a QoS aware middleware architecture that abstracts the wireless interface an application runs on, and obviates the need for application developers to have an in-depth knowledge of the underlying wireless technology. His proof of concept was deployed on a wireless testbed sponsored by the UK Mobile Virtual Centre of Excellence (www.mobilevce.com)

Nathan has also designed and deployed industrial automation systems for managing distributed processes and telemetry. He has written and deployed a good number of distributed applications (for mobile, web and desktop), often with intermittent connectivity between hosts. His other interests include development of low cost alternative technologies for emerging economies, and pervasive (ambient) networks.

He received his Ph.D in Electronic and Electrical Engineering from the University of Strathcldye inGlasgow, UK in 2004, and is presently an assistant professor at the Ashesi University. Courses he teaches include Networks and Distributed Computing, and Mobile Web Programming.

[1] Photos and biographies source: http://www.ashesi.edu.gh/



G. Ayorkor Korsah has a Ph.D. in Robotics and Artificial Intelligence from Carnegie Mellon University in Pittsburgh where she was affiliated with the rCommerce and TechBridgeWorld research groups. Ayorkor's research interests include designing algorithms for robotics planning and coordination, and exploring the role of technology in education in developing communities. Ayorkor was visiting faculty at Ashesi University College in 2003-2004, and joined Ashesi as a full time faculty member in 2011. She teaches Robotics, Programming, Data Structures and Algorithms.

Astrid Twenebowa Larssen has a Ph.D. in Interaction Design from the Interaction Design and Human Practices Lab at University of Technology, Sydney, Australia. Her research activities and interests include human-computer interaction and interaction design, movement understanding as a "design sens-ability" in interaction design, everyday mobile technology use practices in emerging economies, female participation in CS education and in the CS profession, teaching as facilitation, and teaching reflective practitioners. As an Assistant Professor at Ashesi University College, she taught Human Computer Interaction, Software Engineering, and Design.

3. iSTEP 2012 PREPARATION

The iSTEP 2012 program involved a full year of preparation by the TechBridgeWorld team. Partner discussions took place the previous summer to confirm expectations on both sides and determine the focus of the research projects. The partner location was also vetted by international security contacts so that the risks of sending students overseas were understood and managed. CMU students were recruited to apply for iSTEP during the fall 2011 semester. By the end of the calendar year, finalists were notified and the iSTEP 2012 team was confirmed.

TechBridgeWorld spent over four months training the CMU team for ICTD field research, with specific assignments geared to the research projects they will conduct during the summer internship. In coordination with several departments at CMU, TechBridgeWorld hired the interns for the summer, booked travel arrangements, applied for research compliance approvals, processed legal agreements related to the partnership and student participation, and fundraised to cover program costs. International airfare, visas, and stipends for the interns were paid for by the resources raised by TechBridgeWorld. Ashesi covered for housing and local transportation costs.

Throughout the students' preparation and internship, TechBridgeWorld was available as mentors and supervisors, linking the students to additional advisors as needed. TechBridgeWorld also maintained frequent contact with the partners prior to and during the iSTEP internship to process visas, arrange housing and transportation logistics, and discuss collaboration between the Ashesi and CMU interns.

3.1 Team Preparation

Prior to traveling to Ashesi, the CMU team spent 16 weeks preparing for the 10-week research projects during in the spring academic semester. The five CMU students first took a "mini" course of 6 units, followed by an independent study for the same amount of units. During these courses, the students learned how to work together as a team, prepared for their individual roles, and did background research to make the 10 weeks at Ashesi as productive as possible. This included literature reviews, reports analyzing Ghana and the project partner location, media and management plans, and travel information for the trip to Ghana. The first set of goals of the internship were to create an organizational structure within the team, develop individual and group task plans, and begin to better understand the resource systems at Ashesi. At this entry stage the iSTEP team began to understand the literature and performed basic interviews with experts within CMU's and TechBridgeWorld's network. The team also began to gather information on Ashesi University College through communications with Ashesi partners.

3.1.1 Assessment Coordinator

Preparation for this role began with background research into the target country and community for iSTEP 2012; i.e. Ashesi University College in Ghana. In particular, it was important to become familiar with Ashesi's history and TechBridgeWorld's previous work within Ghana, which offered some context for the iSTEP projects. Additionally, various methods for collecting and analyzing data were studied in order to select the most appropriate approaches for the given target community and projects. This research focused on literature related to assessment of field research projects, particularly in ICTD. The PREval Framework [8] and Qualitative Research Methods: A Data Collector's Field Guide [9], were key resources used to prepare for the iSTEP 2012 assessment work.

In preparation for the work in the field, an assessment plan was created to outline a rough timeline for assessment related tasks. To supplement this, an evaluation plan, draft surveys, interview questions and other material to be used for data collection were developed. Some of these documents were submitted as supporting material for our application to CMU's Institutional Review Board (IRB), whose approval is required when conducting research involving human subjects. Submitting all IRB documents in a timely manner is a critical step in field research projects, since IRB approval is needed prior to collecting any data in the field. Familiarity with the content of and procedure for handling consent forms and other IRB protocols was necessary to be well prepared for conducting surveys, interviews and focus groups in the field.

Finally, given the time constraints of the internship, it was valuable to collect as much baseline data as possible prior to departing for the field. A baseline survey was electronically distributed to the target population before departure from Pittsburgh. LimeSurvey[2] open-source software was utilized for creating and managing this survey. Information gathered through this survey helped the team to further develop project plans.

3.1.2 Project Manager, Waste Project

The waste project manager was responsible for overall coordination and execution of the waste monitoring project. During the initial phase of the preparation, the team worked together to develop an understanding of the objectives of the waste project and logistics of working in Ghana and at Ashesi to identify needs and challenges relevant to the waste project. This included working with the assessment coordinator in the development of relevant needs assessment questionnaires to gain an understanding of the project objectives, goals and expectations from the team and to identify various user groups for the survey. A literature review was conducted to identify areas for improvement, existing technologies and tools for waste management. The project manager coordinated with the software developer to identify the technical feasibility of the technologies and tools identified in the literature review and

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[2] http://www.limesurvey.org/

worked with the dissemination coordinator in the development of social media and communication guidelines.

For further preparation, the team met with the CMU green practices team to develop an understanding of the environmental management processes and their development. Lastly, the project manager developed a team motivation plan to keep the team connected and a team safety plan. The detailed management plan developed by the team laid out the basic framework for project management.

3.1.3 Project Manager, Water Project

The first preparation stage of the water monitoring and management project was to set the stage for the remainder of the internship. This period of the water project was performed prior to going to Ghana. During the next preparation phase the team drew from the basic research provided by the literature and began to tailor solution sets and develop a more detailed field research agenda to Ashesi. Here, technical members of the team drew from the initial interviews and research to create a basic set of technical considerations, constraints and possibilities. Similarly, the needs assessment coordinator was able to use the research to create an in-depth field research plan.

3.1.4 Software Developer

Preparation for the role of software developer was initially focused on being an active member of the CMU iSTEP team. The developer assumed priority on technically focused subject matter. Later in the semester-long preparation, the focus became preparing the team for technical fieldwork including preparing a file backup plan, shared team calendar, naming convention guide, and visualization and management tools for a dummy database.

3.1.5 Dissemination Coordinator

This role was responsible for managing the dissemination of the team's research and internship experience to appropriate audiences (e.g. academia, ICTD research, funders, CMU community, Ashesi community, etc.). This included daily management of the team's various media initiatives as well as the management and production of a final technical report and final presentation.

Preparation for this role in the spring semester included developing a media and dissemination plan to be implemented during the internship. The media plan included strategies for reaching various audiences by utilizing web 2.0 and provided schedules for social media posting, video creation, sending of bi-weekly e-mails and VIP e-mails. Furthermore, the dissemination coordinator was responsible for leading the design of the iSTEP 2012 website and setting up the social media channels. By the start of the internship, all media channels were updated to reflect the current iSTEP year, location and projects. Lastly, preparation included creating (1) an online kit of consumable materials for the media and (2) coming up with a template and outline for the internships' final technical report.

4. iSTEP 2012 PROJECTS

4.1 Waste

Currently Ashesi does not have a waste management policy and framework in place. Ashesi has a unified waste collection process and waste collected from bins is aggregated at a central location and disposed of by a third party contractor. Currently there is no system for measuring and monitoring the quantities of different types of waste

Through the iSTEP 2012 internship, Ashesi envisions to develop waste monitoring practices with the following intent:

- To know the amount of waste generated on campus.
- To be able to sort waste and know how much of each kind of waste is generated.
- To identify different third party contractors in Ghana that recycle different types of materials.

There has been an increasing trend of development of higher educational institutions globally both in-terms of number of students catered to and in terms of the real-estate space consumed. Some of the universities have grown to the size of small urban municipalities and have posed a challenge to resource management for both the administration and the local governments. As a result, sustainability of the waste management practices to suit the growing university needs has become a concern for the administration and the policymakers. The following are some of the key ingredients to successful environmental projects at educational institutions [10]:

- Understanding of the activities/work of the educational institutions
- Understanding of the decision making system and the commitment towards environmental actions
- Funding
- University wide coordination
- Communication and knowledge/awareness generation
- Implementation support/contractors
- Continuation/scalability plans

Universities have the potential to catalyze and accelerate societal behavioral trends and the integrated solid waste management practices developed and practiced by these universities will act as a model of sustainable community development.

4.1.1 Current System of Waste Monitoring at Ashesi

The Ashesi campus is spread over 25 acres of land and has both academic and housing facilities. The academic building primarily houses the classrooms, library, faculty and administration offices. The hostel building has the capacity to host up to 320 students. The campus hosts a kitchen that caters to the dining needs of the residents of the campus. The campus also has a convenience store in the academic building and a small snack shop in the hostel building.

In order to understand the existing system of waste collection and disposal, detailed interviews were conducted with various stakeholders and contractors. The understanding gained is presented in the following section.

Waste Collection

In the current setup, small green colored dustbins (Figure 3) are placed in different locations around campus. Trash from individual persons is collected via small green-colored bins. Every morning, from Monday to Friday, cleaning services personnel dispose of the garbage from the green bins into larger 240-liter garbage bins (Figure 4) located at strategic positions in and around the academic and hostel buildings.

Figure 3. Small green colored bins

Figure 4. 240-liter big garbage bins

Waste from the cooking area of the kitchen is discharged directly into 240-liter garbage bins, while the waste from the serving area is collected into cardboard boxes that are then dumped into 240-liter garbage bins located next to the serving area.

Some of the students in the hostel building maintain small plastic bins in the hostels and the waste from these small plastic bins is dumped into 240-liter garbage bins located in the hostels. In addition, waste collected from small garbage bins placed in bathrooms is also dumped into the nearby 240-liter garbage bins on a regular basis by the cleaning staff.

The team conducted a manual mapping of different garbage bin locations across the academic building, hostel buildings and kitchen. On the day it was mapped, the campus had 26 small green colored bins and 24 240-liter garbage bins. A diagram depicting the location of garbage bins and the collection points across the campus is presented below (Figure 5). It has to be noted that 240-liter garbage bins present are of different colors. Discussion with Operations management personnel indicate that the different colors are to be used for segregation of different materials (green for organic waste, blue for plastic, yellow for paper etc.). However, as of now no source segregation is done and all the bins are used for the same purpose.

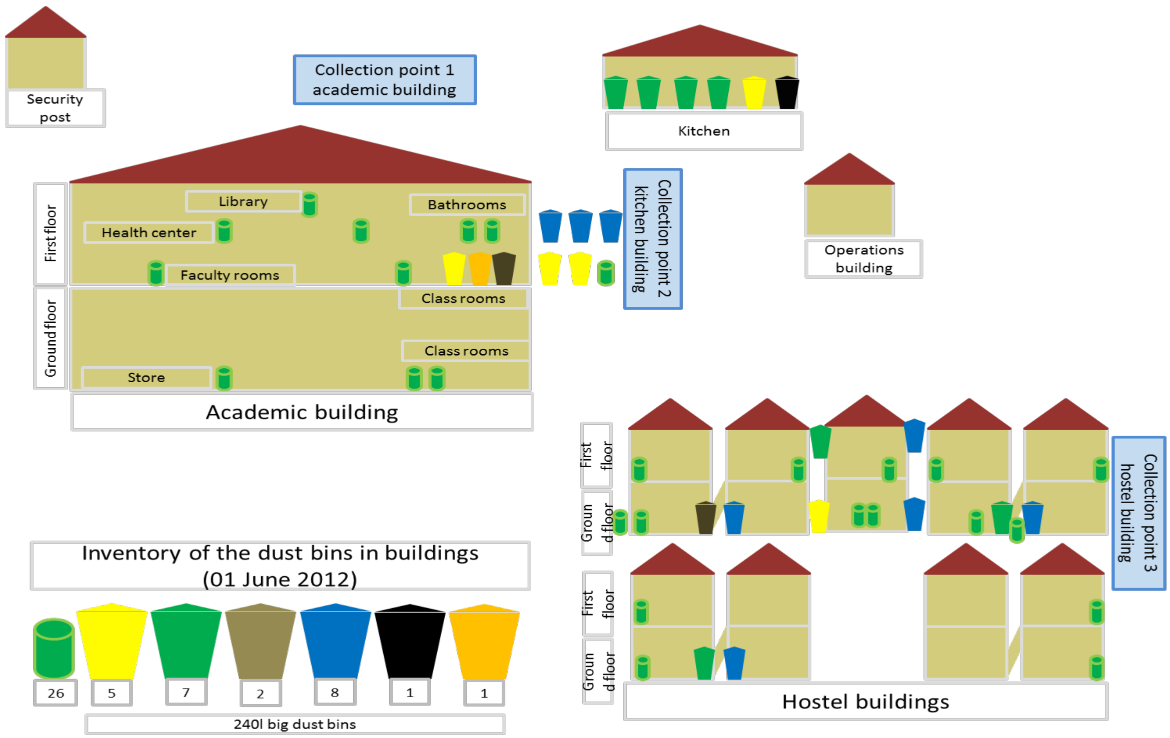


Figure 5. Location of garbage bins and the collection points across the campus

Waste Disposal

The 240-liter garbage bins that are filled are moved to one of the three collection points (Figure 5, collection points marked in blue boxes). The bins from the academic building are moved to collection point 1, the bins from the kitchen are moved to collection point 2 and the bins from the hostels are moved to collection point 3. A third party garbage collection truck collects the garbage from the collection points. Once a week on the weekends (mostly Saturdays), the garbage collection truck empties the filled 240-liter garbage bins into the collection truck.

Costs and Environmental Considerations

Since November 2011, Ashesi pays GHC 30 per month per one 240-liter big garbage bins for collection and disposal of waste. In total, Ashesi pays GHC 900 per month to the third party garbage collector for collection and disposal of 30 240-liter big garbage bins of waste for the entire campus.

As of June 2012, there was no procedure for segregation and recycling of waste on campus. Discussions with the third party garbage collector indicate that a landfill (approximately 4 kilometers from campus) is used for disposal of the waste collected on campus.

4.1.2 Literature Review

In order to develop an understanding of the existing waste monitoring solutions that can address the challenges and needs of Ashesi a literature review was conducted. The focus of the literature review was to find out different methods currently used to monitor waste on college campuses and in similar institutions around the world and understand the technological solutions being used. The following sections present an overview of the waste management models, key observations from the case studies of development of waste monitoring practices in Universities around the world, technological solutions being used and insights to build a framework for waste monitoring in Ashesi.

Waste Management Models

Waste management models for municipal waste management have evolved over decades. These models present the policy/decision makers with possible scenarios for maximizing efficiency and minimizing resources. Current waste management models can be categorized into three categories:

- Models based on cost benefit analysis: These models take into consideration only the costs and benefits associated with various waste disposal options. These models however do not look into the environmental impacts of the waste disposal options
- Models based on life cycle analysis: These models take into consideration the environmental aspects throughout the lifecycle of the product. From raw materials procurement to usage to disposal, these models assess the environmental impacts.
- Models based on multi-criterion decision analysis: These models are an advancement of cost benefit analysis with weightage to environmental factors as adopted in life cycle analysis.

There has been an increasing trend in adoption on models based on multi-criterion decision analysis [11]. Developing nations typically start with multi-criterion decision analysis and move towards life cycle impact analysis. The case studies of universities presented below indicate that the universities also adopt multi-criterion decision analysis.

Technology Use in Waste Management

Traditionally waste management has been confined to the realms of low technology management. The advancement of simulation tools and techniques led to development of decision support systems for multi-criterion decision analysis simulations. Software packages are commercially available for municipal solid waste management simulations. However, there have been no indications of use of such simulation packages for universities.

Radio Frequency Identification (RFID) and communication technologies for solid waste bin and truck monitoring systems, RFID based hazardous waste management platform establishment, RFID for early detection and evaluation of waste for collection and monitoring have been observed in developed countries. However, there have been no indications of use of such technologies in developing countries and in university environments.

Case Study: Waste Management at the University of Southampton

University of Southampton (UoS) is one of the largest universities in England with a student community of more than 23,000 students. UoS developed a comprehensive waste strategy based on Political, Economic, Social, Technological, Legal and Environmental (PESTEL) framework.

Summary of the development of waste management practices is presented below:

Table 1. WRITE CAPTION HERE

Phase – key agenda	Key tasks	Key stakeholders
Phase 1 Late 1990s to 2004 Introduction of pay-by-weight system	• Voluntary recycling • Pilot source segregation • Development of strategy • Setting up a waste management team	• Active individuals • Strategy based on source analysis • Students union
Phase 2 2005 to 2007 Set-up of source	• Team expansion and recruitment of environmental manager • Sustainable purchase policy	• Estates and facilities department • Students union

segregated recycling scheme	• Environmental and sustainability policy for campus • Roll-out of recycling schemes on campus • Environmental awareness week • Re-use and re-cycling projects at residence halls	
Phase 3 2008 to 2010 Switch to co-mingled recycling scheme	• Environmental Champions • Pay-by-weight contractors with contractors • Pilot mobile-phone take back service	• Estates and facilities department • Students union
Phase 4 2012 (provisional) Reduction in overall carbon footprint	• Separate food waste collection	• Estates and facilities department

Increasing cost of landfills, taxes and evolution of the regions environmental practices/laws also guided the shaping of the UoS environmental practices. Through this phased strategy, UoS has achieved close to 75 % recycling rates in 2007-08 [10].

Case Study: Waste Management at Universidad Autonoma Metropolitina

The Universidad Autonoma Metropolitina (UAM-A) Azcapotzalco campus (UoS) is one of the largest universities in the region with a student community of more than 12,000 students and a ground coverage of 190,513 sq.mts. UAM-A has implemented an integrated solid waste management program and the summary of the development of waste management practices is presented below:

Table 2. WRITE CAPTION HERE

Phase – key agenda	Key tasks	Key stakeholders
Phase 1 October 2003 to July 2004 Efficient waste separation	• Voluntary recycling • Increased waste collection infrastructure • Separate bins for recoverable and non-recoverable wastes • Information campaigns	• Active individuals • Students union
Phase 2 July 2004 to November 2005 Set-up of source segregated recycling scheme	• Designing and developing efficient collection systems • Training and workshops for workers • Information dissemination amongst the community • Evaluation of pilot waste collection data	• Facilities management • Students union • University community
Phase 3 From November 2005 Switch to co-mingled recycling scheme	• Focus on final destination of waste collected • Consideration of organic treatment • Re evaluating and designing procurement agreements	• Facilities management • Students union • University community

Environmental commitments by the university and evolution of the local environmental practices/laws also guided the shaping of the UAM-A environmental practices. UAM-A's integrated solid waste management strategy has been considered as an advanced program on a county level [12].

Case Study: Waste Management at Carnegie Mellon University

Carnegie Mellon University (CMU) is one of the largest universities in the United States with a student community of more than 10,000 students. CMU plan for an expanded environmental practices program on campus started in 1999. Summary of the key initiatives taken for waste management are presented below:

- Sampling and characterization of solid waste generated on a pilot basis
- Estimation of daily waste generation
- Data recording and analysis
- User awareness generation and waste segregation at source

Though the sample waste management audit indicates a recycling potential of 40% currently CMU recycles at a rate of 26% as of 2011. Some of the recent initiatives of food waste composting by tying up with the local county recycling program will help CMU attain the targeted 40% recycling rate.

Discussions with the facilities management professional at CMU indicate that increasing cost of landfills, taxes and evolution of the regions environmental practices/laws also guided the shaping of the CMU environmental practices. Involvement of students, faculty and the guiding principles of the university to maintain a green environment are the building blocks of the current waste management practices.

4.2 Water

Ashesi's commitment to technology and sustainability can be seen in its rainwater collection system. Implementation of a rainwater collection system and a borehole well enables Ashesi to meet its water needs even though its peri-urban location in Berekuso is far from the reach of Accra's municipal water lines. A biogas digester converts sewer water into fuel, which is channeled throughout the campus for cooking needs; in contrast to the country's standard practice of dumping sewage into the rivers and Atlantic Ocean. See Appendix I for a description of the biogas plant.

4.2.1 Current State of Water Use at Ashesi

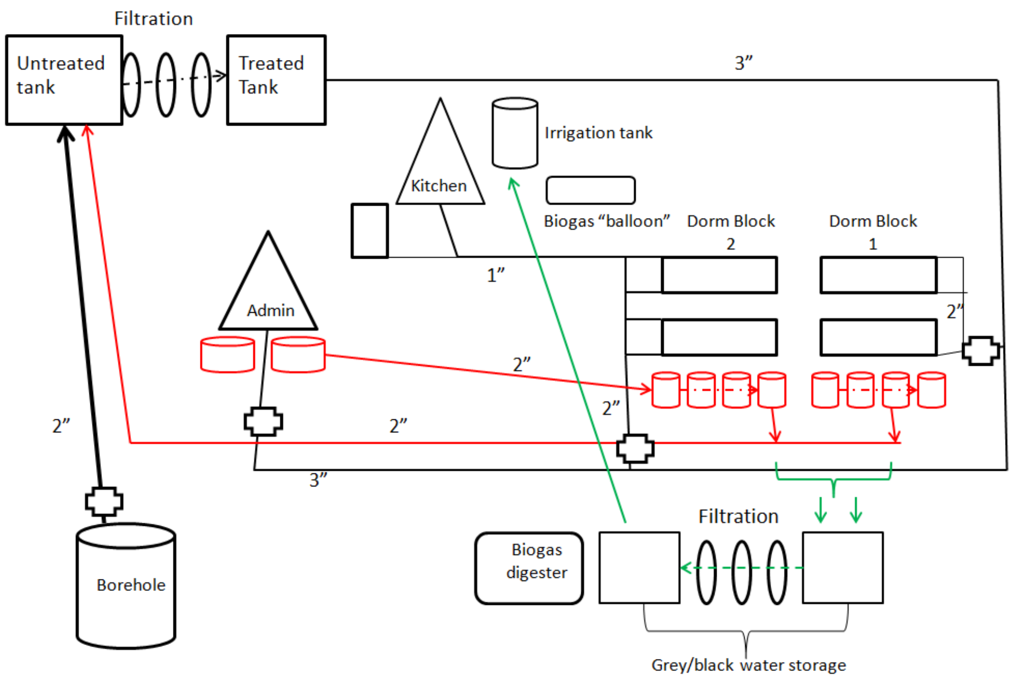
The water monitoring and management project resembles many aspects of the waste monitoring project. The goal was to understand the current infrastructure, facilities, and capabilities of water on campus, as well as the common behaviors of water usage by the campus population. After assessing what is known, we could find solutions to monitor water levels and create a technical system that would aid in this monitoring and management of water.

Summary of the Water System[3]

Ashesi's water system has three main components: water sources, treated water, and waste water. Source water comes from a borehole and nine rainwater tanks located under the administrations building and two dorm blocks. Treated water flows through the system from the treated water tank (regardless of source) into the three main campus blocks (admin, kitchen and dorms) from the main 3" pipe that flows around campus. Water breaks from the main line in three spots, to the admin building, to dorm block 1 and to dorm block 2 and the kitchen (one break for both block 2 and the kitchen).

[3] This information was gathered via relevant interviews and observations

Waste water is separated at the source from grey and black water and flows in separate pipes to the biogas system roughly 50 meters down the hill from the dorms. From there both grey and black water is purified (to meet grey water WHO standards) and drained to the nearby hill. For details on tank and pipe sizes see Appendix II. In the map below (Figure 6), you can see the cycle of the water system on campus.



Key:

Black- Main piping to buildings | **Red**- Rainwater tanks/pipes | **Green**- waste water (grey and black)

= Underground rainwater tanks | = current above ground, analog, water meters (data in M3)

Figure 6. System Map

Water from the Borehole

The borehole that supplies an estimated 60% of Ashesi's water is 250 meters west of campus and approximately 61 meters down (Ashesi is located on a hill). Water is pumped up the hill at 100L per minute into a holding tanking that holds 75,950L and split evenly into two compartments, treated and untreated. The treated water tank is large enough for 1.5 days use. Therefore, the pump at the borehole generally runs from 8am until 5pm and is shut off for the night due to sufficient water storage in the primary holding tank. Each morning the tank is then close to being empty. In the event the treated water tank is empty it takes roughly an hour for water to begin to be filtered from the untreated tank, through the filters, into the treated tank, and into campus circulation for consumption.

Treatment System

There are three treatment systems on campus: (1) the main treatment station where all borehole, rainwater, or purchased untreated water is treated before entering the system, (2) mini filters placed along the pipe line to further soften water, and (3) the biogas treatment plant that purifies grey and black water.

The main treatment system channels water from the unfiltered water tank into three filters: iron filtration (takes out iron), filox (removes remaining iron dissolved, manganese, etc.), activated carbon (softens, takes away color and smell), and UV which eliminates remaining germs. Per our literature review and conversations with the environmental consultants, this filtration system is standard. Water is currently tested once a month by the Council of Scientific and Industrial Research for quality. Originally, the IFC requested quarterly testing but an initial finding early on of higher than desirable manganese levels prompted the campus to begin testing once a month. Since testing monthly, the water quality has consistently met potable requirements.

Furthermore, there are also three filters on the pipes around campus to remove "scales" from the water. Scales are buildup along the pipes that cause fractures. While water quality meets the World Health Organization (WHO) standards, the water was still leaving sediment buildup and causing pipes to burst. These three filters are meant to address those concerns.

Rainwater

Each of the eight dorms has a holding tank for rain water collection beneath the dorms and one underneath the administration building. The administration building's tank is separated into two compartments, one which is always filled for fire relief and one that is used for consumption. Each of the eight tanks is large enough to meet current demand for one day, for a combined total of nine days. The rainwater tanks under the dorms have a valve that allows water to pass between them in order to fill evenly, as well as a valve that shuts off each individual tank. In order to consume rainwater, water from the administration building's tank first runs into the dorms and then directly into the untreated water tank where it is filtered as water from the borehole. The piping system is similarly sized and structured as the treated water pipes (2" lines). The pressure in the system is sufficient to move rainwater from the numerous storage tanks to the untreated water tank without a pump.

Waste Water

Once water is consumed, similar piping structures exist for waste water (ranging from under 32cm up to 150cm) to flow to the biogas plant located roughly 50-100 meters down the hill behind the dorms. Both grey water from campus use and black water from the latrines flow to the biogas chamber but in different piping. Sewage water flows into the bio-digester where black water decomposition occurs. Water from the bio-digester runs into a gravity filtration bed with activated carbon to remove color and odor. Finally, water runs to an ionization system that removes the remaining pathogens to meet the WHO standards for grey water. The goal of the system is to pump treated grey water up roughly 300 meters to a plastic tank that is above ground near the cooking area which will then be used for watering vegetation. However, the pump in the biogas chamber is too small to pump water the distance of the above ground tank and therefore all treated "enriched" water is released onto the nearby hillside. Because grey water is isolated from the rest of the water system, moving the holding tank will not solve the problem because the system needs enough pressure to reach irrigation areas.

Now that the two projects have been identified, the following section describes the process in which we informed our research.

4.2.2 Literature Review

The purpose of this literature review is to summarize the literature on water monitoring and management solutions and concepts used on college campuses and in similar institutions within Ghana and in other developing countries. Because technical and non-technical solutions are always contextual, creating an appropriate framework for addressing water issues is always an important and pervasive element within the literature. To that end, this literature review is not isolated to simply the “tools” that are used, but the methods of analysis, including participatory research, risk management in water resources, and the concept of “appropriate technologies”. While technical solutions often steal the headlines, the backdrop of successful water management systems in developing communities—particularly small-scale areas such as colleges and universities—revolve around overcoming coordination problems, creating buy-in, and supporting local knowledge. Therefore, those elements are addressed as well. The purpose of this literature review is to review small-scale water use in countries like Ghana; however, much of the literature focuses on urban areas within developing countries. On one hand, urban areas are unique entities with specific collective action issues that are separate from those of rural or college communities. On the other hand, many of the issues related to creating buy-in and making technical solutions sustainable in urban areas are similar to those faced by water managers in more isolated areas, and therefore, the literature on urban water use is useful.

This literature review is broken down into themes in the literature. Section one addresses the macro themes across any water monitoring solution: risk management and appropriate technologies. Without a base concept of how risk is addressed and how water use has changed, technical solutions are often myopic. Section two looks at water use in small communities and identifies particular technical solutions. Section three evaluates the literature on water solutions monitoring strategies on college campuses.

Appropriate Technology

The concept of “appropriate technology” is widely associated with Dr. Ernst Schumacher’s book Small Is Beautiful [13]. The term is often discussed in ideological and not scientific terms but is generally meant to encompass technology that is small-scale, labor-intense, energy-efficient, environmentally sound, and locally controlled [14]. Beyond the normative considerations, the more applicable definition for ICTD researchers is adopting the simplest technology that solves a given problem. While the general notion is not particularly novel, appropriate technology comes up often in the literature as a way of benchmarking a technical solution within the contextual environment where the solution will be used. This is particularly relevant when one considers the economic factor inputs of a water system. For example, water monitoring technology throughout the United States and Western Europe are produced in a context where capital costs are increasingly lower than labor costs, so technical solutions are easier to replace than to fix [14]. However, in developing economies the opposite is true, and therefore appropriate technical solutions are likely those that are best able to be fixed and not replaced. The overarching concept of appropriate technologies is to address technical solutions within the socio-economic environment of its users. One particular example is the Kick Start Treadle Pump. Kick Start pumps allow users to extract water from ponds, rivers, or as much as 25 feet deep wells by a human-powered kick lever. The devices are easy to transport and cost between $35 and $95 [15]. Irrigation and water pumping have been conspicuous problems throughout Sub-Saharan Africa, particularly in rural and small-scale institutions, because large, expensive equipment has traditionally been the only form of irrigation and pumping. Kick Start Treadle Pumps offer a low cost, versatile alternative.

Risk Management

Water systems should be constructed with specific user needs in mind. Conventional systems of water decontamination and disinfection are chemically and operationally intense, and require considerable capital and engineering expertise and thus are best catered towards large systems [16]. Yet in many parts of the world chemical decontaminants are untenable due to the lack of infrastructure to adequately remove waste and address potential spills, which can have adverse environmental and health consequences, even on a small scale. The appropriate trade-off between additional upfront costs of larger subterranean tanks and additional capacity is contingent upon the scarcity of rain and the risk of being under-resourced. From an engineering perspective, the value of a larger tank can be calculated by average rainfall and user population. However, lack of capital can make such solutions infeasible.

Shaw and Woodward find many decision makers in developing countries are faced with asymmetric information where there is clear evidence of the costs of water resource management but appropriate analysis of the benefits are inaccessible because of a lack of data on use [17]. The authors concluded that in such environment technology is adopted in a risk-averse fashion where decision makers invest too little resources in water management and do not "future-proof" a system. This is particularly true when technologies have high fixed costs. Kato and Ahern suggest the best method of such asymmetric decision making is through "adaptive planning" or "learning by doing" [18]. The authors suggest instead of approaching water technology from a traditional infrastructure project perspective, decision makers should consider projects and ongoing process with four themes: 1) thinking about projects as experiments 2) conducting several plans/experiments at once for fast learning 3) monitoring is essential and 4) learning by doing is a premium value [18].

While attractive, Kato and Ahern's concept of adaptive planning has several practical shortfalls when considering small-scale water monitoring and management. First, the major difficulty in creating monitoring systems in developing areas is the upfront construction costs. In such scenarios it's unclear how Kato and Ahern would approach experimentation. The value of learning by doing is to create a set of localized knowledge that is deeply contextual, yet doing so requires the ability to build, deconstruct, and rebuild. Lockwood et al. comment that a problem with adaptive planning, as it is articulated by Kato and Ahern, is that stakeholders need to be involved on a detailed and long-term basis. However, this is often impractical. Moore and McCarthy worry that adaptive planning may be seriously compromised because of a lack of data, or the ability analyze existing data [19]. Specifically, if the data is inconclusive adaptive planning offers little recourse.

A more technical alternative is to use Integrated Water Resource Optimization Models (IWROMs). IWROMs are resource optimization models that specifically help optimize use, run simulations, and project outcomes across competing water management options. IWROMs applications use hydrological simulators and complex algorithms to model human-nature relationships in regards to particular water policies [20]. IWROMs are particularly useful in areas where water resources are intense and allocation is important. One of the best examples of IWROM is the Nile Basin Initiative (NBI) [21]. NBI is a coordinated initiative of nine African countries along the Nile that have together created an IWROM to monitor how water use amongst member states affects each other state. The project is particularly helpful in clearly showing how state water policy impacts the region. IWROMs are not just useful for large, collective action problems. Mayer and Munoz-Hernandez also point out that IWROMs are important in areas that have limited resources and limited knowledge, where the value and cost of experimentation is high [20]. Small-scale users that are "off-grid" such as remote college campuses could also use an IWROM to simulate alternative options prior to construction. However, outputs do not always reflect causality and the ability to interpret results is still an essential skill that many remote water municipalities lack [22]. Jakemen and Letcher remind users that the "level of uncertainty goes beyond unexplained by randomness to a situation where many fundamental? model outputs are unknowable in a traditional, objective, scientific sense." [23] To that end, adopting appropriate data collection methods is essential.

Monitoring and Management of Needs of Users

There is a conspicuous need for more data collection in water systems. In order to develop, maintain, and adapt sophisticated water systems, geological information, hydrostratigraphic information, historical pollutant records, field data, quality standard data, and other data points are important [24].

However, collecting such data and keeping consistent records is a challenge for water managers in both developing and developed regions. Developing municipalities generally have an advantage because of more clearly mandated data policy. Environmental and public safety concerns over water throughout Europe and the United States have historically been more pronounced than throughout the rest of the world, and therefore Freedom of Information and data procurement legislation are more codified. Access to technology is also obviously more prevalent in affluent communities. But the legacy of paper-based data collection throughout Europe and the United States has also hamstrung the use of more advanced ICTs. Here there is an opportunity for developing countries to leapfrog developed countries as administrators develop new water monitoring policy and data requirements in conjunction with broader ICT adoption they may surpass institutional inertia that is often cumbersome in Europe and the United States (recently developed Eastern Asian countries offer a strong example of public administration developing along technological adoption). The most promising mechanism for data collection for Sub-Saharan Africa will be to build monitoring technology into the system. For example, while underground tanks are being constructed, internal monitoring technologies should be procured and installed with the necessary software. By establishing ICT data collection as a core function of a water system, and not a peripheral component to be adopted in an ad hoc or piecemeal fashion, Sub-Saharan water resource managers will be better positioned to future-proof current water management investments.

Water Monitoring and Management for Small-Scale Use

Water monitoring in rural or remote institutions, such as college campuses, offers unique opportunities and challenges. On the other hand, the complex collective action and coordination problems that hamstring progress in large urban areas generally do not exist in smaller regions. However, the ability to take advantage of scale is a major advantage of urban water municipalities compared to rural areas. The literature mostly emphasizes water monitoring and management within cities in developing areas, however there are case studies in the literature that are applicable to small scale use in Ghana or other developing countries. From a technical perspective, many of the same technologies are being deployed in rural areas of more developed countries as in developing countries. For example, in the Czech Republic the Federal Monitoring Agency has deployed YSI[4] multiparameter sondes sensor devices in rural, wooded areas that are difficult to reach to monitor watershed quality and acid rain content. YSI sondes allow for continuous monitoring, which is far superior to and less costly than the prior method of weekly samplings. Similar YSI sondes sensors are deployed throughout Malaysia. Currently, three YSI sondes sit upstream drinking water locations and three more sit downstream. Every 15 minutes each YSI sensor measures temperature, conductivity, dissolved oxygen and ammonia content in the water [25].

While the funders of the sensors are federal agencies, the usefulness of the YSI sondes is in their ability a) work without much oversight b) have traditionally very low maintenance costs and, c) because the sensor manufacturer (YSI) sells the data acquired from each sensor, not the actual hardware, there is lower upfront costs and little worry of having technology leftover in the event of an upgrade [25]. YSI type monitoring technologies may be desirable to small-scale users such as universities because cost-based risks are lower and each campus does not have to have an in-house specialized ability to run the monitoring system. Each campus instead needs users who are able to interpret the data with the assistance of the technical consultant.

Other sensor technologies are also applicable for small-scale use. In areas that are either large (urban areas) or in very hilly geographies, high pressures in water pipes result in significant water loss and

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[4] https://www.ysi.com/

premature pipe damage [26]. Certain acoustic leak protection sensors are able to detect water leaks and save small-scale users and municipalities large amounts of water, time, and money. For example, in one study of eight southern African cities, Gumbo finds that those with sophisticated leak protection systems were able to reduce unaccounted-for-water (UAW) but much larger margins. In particular, the cities of Windhoek, Bulawayo, and Hermanus, that invested in fixture failure technologies had UAW rates below 20 percent. This can be compared to cities that did not have sensors, including, Johannesburg, Maputo, Maseru, Lusaka, and Mutare, that cannot account for 40-60 percent of municipal water [27]. Several of these cities adopted what are called "advanced pressure management" systems that track water loss through leaks and the overall pressure within a system. The logic behind such systems is simple: pressure, not weak pipes, causes water loss. Keeping the overall water system at the optimal pressure is an important step to maintaining the system. One report found that advanced pressure management systems for the average urban environment in developing countries cost $800,000 while anticipated cost savings per year are $4,000,000 [26]. The authors also found that it is not only important to have accurate flow, leakage, and pressure data, but also to have specialized individuals trained to handle data analysis. This last requirement is obviously easier for large urban municipalities than for small-scale users such as college campuses; while campuses may not be able to hire one person to solely manage water data, decision makers should approach technical solutions with the awareness that personnel skills need to be symmetrically aligned with the technology adopted.

Another technology that has been adopted to use for water monitoring in small-scale environments is Near Field Communication (NFC). NFC, along with RFID chips, allows users to use their cell phones to relay accurate purification metrics to distant laboratories. In remote areas of Haiti, aid workers deliver 5 gallon buckets with chlorine purification kits. In order to collect data on appropriate use, workers use NFC-enabled cell phones to activate the data on the RFID chip (which is attached to the bucket). Researchers are then able to identify the chlorine use and other metrics to assess whether or not water is being purified accurately [28]. Amongst Haitian users, episodes of diarrhea and cholera have declined by 50 percent [28]. Remote universities that have connections to distance technical partners (i.e. researchers abroad) but few local technical partners may find such RFID solutions ideal.

Case Study: University of California Santa Cruz Storm Water Monitoring

In 2000, University of Califiornia Santa Cruz (UCSC) decided to reduce the impact of overflow water from storms on campus. In order to do so the college needed to develop a system of removing water safely and efficiently. Most storm water collection systems are large centralized piping systems, however because of construction cost and the desire for future flexibility, UCSC uses small scale discrete storm water collection systems across campus to remove excess water. Beyond the infrastructure design, UCSC needed student buy-in because the campus did not have monitoring sensors and therefore student reporting of excess storm water was important [29]. Moreover, the storm water drainage system could easily be contaminated with waste and trash, student understanding of the water system was seen as pivotal. In order to promote student awareness the campus developed a survey gauging both interest and knowledge of storm water on campus, created a "storm water quality hotline" for students to easily report storm water, and created an interactive map for students to better understand the system [29]. The example is to express that, although storm water sensors were not in place, the campus found alternative mechanisms for addressing monitoring concerns and raising student awareness.

Case Study: Cornell University's "Take Back the Tap" Initiative

Cornell University has recently created an initiative to reduce the amount of bottled water on campus. Not only is bottled water expensive and harmful to the environment but also creates more waste for the university to process. The goal of the initiative was to create better data analysis of water use (both tap water and bottled water) as well as create an incentive for greater tap water use. One of the strategies adopted by Cornell to increase tap water consumption was to publish a variety of data metrics across campus on water use, costs, environmental impact, which dorms had the highest consumption rates, peak hours, etc. In this sense, monitoring technology was used to leverage student interest in water use and eventually increase consumption of tap water over bottled water [30]. St. Benedict College and George Mason University have similar bottled water programs however these schools have also deployed drinking water fountains that count the number of "water bottles" filled at each station. The stations serve a dual purpose: monitoring water use in terms of bottles of water and allowing students to better understand water use [31][32].

Case Study: Imperial College

Imperial College in London has also adopted water monitoring strategies to better allocate water resources on their campus. The college's specific strategies are to: reduce water consumption by 25%by 2020, provide a water metering strategy across the college which allows monitoring of water consumption to the required detail and accuracy, apply regular building performance against published benchmarks, and apply independent environmental assessment methods to college sustainability efforts [33]. In order to meet these goals the college has invested in a water management system that monitors water use per building and department, has introduced a leak detection system, and measure recycled rainwater and grey water to reduce main water consumption. In order to increase student interest the campus has begun to publish water usage data per building in comparison to stated prior goals and created maps of where to find public drinking fountains on campus.

The consistent theme across the examples of UC Santa Cruz, Cornell, George Mason, St. Benedict, and Imperial College is that water monitoring systems are used to leverage student engagement as well as a source of data. By creating competitions across dorms, increasing awareness of storm water, or establishing clear campus-wide goals, water monitoring increases the interest in water conservationism amongst campus users.

5. NEEDS ASSESSMENT

TechBridgeWorld's approach to field research is to work in partnership with communities across the world to accomplish their vision of development by addressing specific needs within those societies. This is in line with the community-based participatory research (CBPR) approach that has gained traction in several fields, particularly in healthcare [34]. The goal of CBPR is to incorporate local community input and encourage the participation of the target audience in designing and implementing interventions aimed at improving their life circumstances. Thus, solutions are designed to cater specifically to these end users, who become not just consumers of the end product, but also creators and owners of the implemented solution. This type of ownership on the part of target communities leads to more sustainable outcomes. For the iSTEP 2012 projects, researchers followed TechBridgeWorld's general approach and worked closely with the Ashesi community to identify solutions that could address challenges they face regarding water and waste management. In order to accomplish this objective it was necessary to first gain a better understanding of the target community's needs. Thus, a key first step in the research process applied to iSTEP 2012 projects was conducting a needs assessment within the Ashesi community. See Appendix III for needs assessment templates.

5.1 Strategy for Needs Assessment

The overall strategy for the iSTEP 2012 needs assessment was to capture a wide array of information about Ashesi in order to best identify central needs of the target community as they pertained to project themes. TechBridgeWorld successfully utilized this approach for other projects.

5.1.1 Data Collection Techniques

Qualitative information was gathered from key groups within the Ashesi community; i.e. faculty, staff and students. The goal here was to learn about the Ashesi community's current practices and goals for water and waste monitoring and management. For this purpose, researchers utilized a mix of data collection techniques, which comprised of interviews, surveys (both web-based and paper-based), observations, and focus group discussions.

- Interviews were conducted with the stakeholders to understand the goals and objectives of the waste monitoring, and water monitoring and management projects. These one-on-one interactions with key personnel provided detailed information on how Ashesi currently manages its natural resources and disposes of waste.
- Surveys were distributed to gather data on water usage and waste generation behavior and perspectives among different cohorts within the community. In particular, related to the waste project, the survey focused on gathering information regarding knowledge of recycling, awareness of recycling activities on campus, behavior towards recycling activities and their commitment and response for action. For the water project, survey questions were geared towards understanding how the Ashesi community utilized water, their knowledge of where Ashesi water supply originates, and their perceptions on how water could be conserved. A web-based version of the survey was sent out to the Ashesi community prior to researchers arriving on site, so as to expedite the data collection process for needs assessment. However, given the intermittent Internet connectivity at Ashesi, once researchers were in the field, printed surveys were also distributed to improve survey completion rates. Ashesi faculty helped encourage participation in the survey via social media and email announcements, and Ashesi interns helped distribute the paper surveys to additional participants.
- Focus group discussions were conducted to solicit further community input on water and waste management strategies for the Ashesi. The focus groups were conducted by members of the Ashesi and CMU teams.
- Finally, researchers from CMU and Ashesi collected observational data, which complemented and enabled verification of preliminary information received from the Ashesi community.

To supplement the qualitative information gathered from community members and observations, researchers independently collected quantitative measures on water and waste levels at Ashesi. This provided important baseline or comparison data for the evaluation of any interventions implemented to affect these levels. Additionally, it was useful to determine how community perceptions of water use and waste generation at Ashesi compared to these measures. Often, people's perceptions may not accurately reflect conditions in the field. Lastly, this quantitative information provided important context for the challenges Ashesi faces with regard to water and waste management.

5.1.2 Sample Selection

Given that the timing of the iSTEP internship coincided with the last few weeks of the academic semester and much of the summer vacation at Ashesi, the available pool of research participants was significantly limited. Thus, it was not possible to obtain a sample representative of the actual Ashesi population. Instead, a sample of convenience was utilized for each data collection method, particularly for surveys and focus group discussions.

These interviews resulted in a wealth of qualitative information that clearly illustrated a consensus about how water and waste monitoring and management might be facilitated by technology and how the campus community might develop its response to such issues. Questions were developed by the entire team and focused on three main areas: current conditions, needs, and goals.

Interviews

Interviewees included personnel from the Office of the President, the Executive Management team, the Office of the Dean of Student and Community Affairs, the Office of the Dean of Academic Affairs, Operations Management, Information Technology, third party contractors involved in waste collection, as well as faculty and staff associated with iSTEP 2012. Interview participants were chosen based on their level of involvement with the project, the project's potential impact on them or their position within the Ashesi community, and the amount of relevant information they could provide relative to consideration of solutions. Thus, these were key stakeholders who have a long-term commitment as Ashesi leaders and employees, so their perspectives were valuable for understanding the motivations behind Ashesi's interest in these projects and how these projects could support their strategic goals in the longer term.

Surveys

A total of 72 Ashesi students participated in the surveys. According to Ashesi administration, enrollment from the previous academic year (2010-2011) was 501 students. Thus, the survey sample included about 15% of the total student population. Table 3 presents the distribution by academic class of Ashesi student survey respondents compared to the total Ashesi student population.

Table 3: The percentage of freshman, sophomores, juniors and seniors among survey respondents, juxtaposed with these percentages for the entire Ashesi student population.

Class	Survey Respondents	Total Student Population
Freshmen	25%	32%
Sophomores	10%	26%
Juniors	22%	24%
Seniors	43%	18%

Although the survey sample was not representative of the entire Ashesi community, responses were received from students of all classes as well as several faculty and staff. Additionally, senior students were the majority group of respondents, and as such the feedback received was primarily from students who presumably had the most knowledge about and experience with Ashesi. In total, 102 survey responses were received: 72 responses from Ashesi students; 1 response from a visiting student; 8 responses from faculty; 19 responses from staff; 2 responses from outside consultants connected to Ashesi.

Focus Groups

Focus groups comprised of a total of 13 students, 3 faculty, and 7 staff. Two student focus groups were held (one related to water issues, one related to waste issues). The majority of student participants were first years since the pool of candidates for the focus groups was limited to those taking summer courses or participating in summer activities on campus. Similar challenges were experienced when recruiting participants for the faculty and staff focus group which covered both water and waste issues. Thus, focus groups did not capture opinions from all key groups at Ashesi, but rather offered initial insight into the perspectives of its students, staff, and faculty.

5.2 Waste Project Needs Assessment Findings

5.2.1 Qualitative Results

Overall, feedback from the community indicated that there is motivation to improve Ashesi's waste management strategy so as to become more environmentally friendly. In order to accomplish this, needs assessment findings suggested that creating more awareness around Ashesi's waste generation and management could encourage active community participation in improving Ashesi's ecological footprint, particularly through practices such as waste segregation and recycling.

Interview Findings

Stakeholder interviews revealed the following key goals for the Ashesi campus regarding how waste is managed and monitored:

- Maintain a campus devoid of litter that properly handles waste by segregation and reuse.
- Measure and monitor waste generation on campus on a regular basis.
- Use waste generation data to develop and implement effective waste management policies, including a recycling strategy.
- Move to a more cost efficient waste disposal system.

Overall, three clear themes for Ashesi's waste monitoring and management needs emerged through interviews with key personnel:

- ***Reliable data collection and organization*** through the development of a system that provides information regarding waste generation on campus.
- ***Awareness generation*** to educate the campus community on how waste produced at Ashesi impacts its surrounding environment and neighboring community, and thereby promote more environmentally friendly practices such as the use of recyclable materials.
- ***Planning and implementation*** of sustainable waste management strategies in partnership with local communities; for example, through identifying different options for organic composting and recycling waste materials.

Survey Findings

Survey responses offered insight into the Ashesi community's perspectives on recycling as well as their willingness to get involved in strategies for improving Ashesi's recycling efforts. Overall, Ashesi students, faculty and staff survey respondents indicated that they:

- Were knowledgeable about the concept of recycling
- Felt that recycling is important and effective
- Were interested in source segregation of trash
- Were interested in raising awareness around better waste management practices at Ashesi

Thus, there was clearly potential for implementing waste recycling measures on campus. However, some respondents were not aware that the campus did not currently recycle waste material. There is a need to improve awareness of Ashesi's waste management practices in order to encourage community involvement in making the campus more environmentally friendly.

Focus Group Findings

Following the analysis of waste generation patterns on campus, focus group meetings were conducted with different stakeholders. The purpose of these focus group meetings were to get an understanding of which efforts would be most effective to generate awareness of waste issues on campus, how stakeholders feel about segregation of specific types of waste and their perspectives on potential solutions to managing waste. Furthermore, these focus groups served as an incubator to test the understanding of the current conditions the proposed solutions and to assess how the campus community would respond to proposed solutions and policy recommendations. The needs assessment team conducted two focus groups during the end of the fourth week of the internship. The first focus group was with students and the second focus group was with faculty and staff.

Student Focus Group

Eight freshmen participated in the student focus group discussion. The high number of freshman was due to the timing of the iSTEP 2012 internship which coincided with Ashesi's summer sessions which offer courses to mostly freshmen. The session lasted for about 50 minutes and the following topics were discussed:

- What are some of the ways you think we can deal with the different kinds of waste
    - Plastic bags – considering that there is limited potential for recycling (because of the thickness of bags, their condition of usage)
    - Styrofoam – considering that it is not recyclable at all
    - Plastic bottles/tins – has potential for recycling
    - White paper – though generated in less quantity is recyclable
    - Water sachets – given that Ashesi has a water purification system and the water is tested every month what should be done to increase consumption of tap water
- General ideas regarding organic waste and disposal

Faculty and Staff Focus Group

A total of seven staff and three faculty participated in the focus group meeting. The session lasted for about 50 minutes and the following topics were discussed regarding waste:

- What are some of the ways you think we can deal with the different kinds of waste
    - Plastic/polythene bags
    - Plastic bottles/tins

    - White paper
    - Water sachets
- In what ways do you think that consciousness can be built about water and waste issues on campus
- In what ways do you think you can supports students in building environmental awareness
- Mentoring a student environmental club, lecturing, seminars, etc.,

5.2.2 Waste Audit

There was no system or activity in place that facilitated operations personnel to collect data about waste generation at Ashesi. Therefore, no historical data was available about waste production levels on the campus prior to the iSTEP project.

In order to approximate the level and types of waste accumulated at Ashesi, an audit was conducted to weigh and segregate trash collected over the course of one week. Given that many people within the Ashesi community were away for the summer break during this time, the data collected were not representative of actual waste levels generated when the campus was at full capacity. However, this initial measurement offered a reasonable estimation for waste generation at Ashesi.

Methods

This waste audit was a structured process that comprised of three main steps: plan & collect, sort waste, and record data.

Step 1: Plan & Collect

First, locations and procedures for weekly trash collection were identified so as to map out key data collection points and times for the waste audit. The goal was to obtain a measurement for a week's worth of Ashesi's waste accumulation. Three locations across campus were designated key waste data collection points (see Figure 5, where collection points are marked in blue boxes).

- Collection point 1: administration building
- Collection point 2: kitchen building
- Collection point 3: hostel building

Next, tools necessary for the audit were gathered, including a weighing scale for measuring the weight of waste, plastic bags for storing the different kinds of waste segregated, gloves and face masks for the personnel involved in the waste audit, and antiseptic hand wash to be used after the waste audit. Additionally, based on expert feedback from Ashesi staff, a list of the main categories of waste generated on campus was compiled. Key types of waste included plastic, paper, organic material, and glass. Finally, a team comprised of researchers and support staff gathered the trash accumulated at each of the previously identified key waste data collection locations.

Step 2: Sort Waste

The waste audit was conducted during a few hours on a weekend day, prior to the weekly scheduled trash collection. Waste bins from each data collection point were emptied individually onto the ground, and separated according to waste type. The segregated waste was then placed in different plastic bags. Any leftovers on the ground were cleaned before the sorting concluded.

Step 3: Record Data

Each filled plastic bag was placed on a weighing scale and its weight was recorded along with the total number of bags filled for each type of waste. Further, all bags were deposited back into the original waste bins so as to reconcile the number of bins filled with the number of bins at the start of the waste segregation at each location.

Results

Detailed findings from the waste audit are presented in Appendix IV. Overall, organic waste comprised the overwhelming majority type of waste generated at Ashesi (64%). Other key types of waste included plastic bags, cardboard, tissue paper (toilet paper), and plastic bottles (Table 4). Specific results included:

- Collection point 1 (administration building) produced five 240-liter big garbage bins weighing 44.5kg in total. Tissue paper, white paper, plastic bags, organic waste, plastic bottles, and non-recyclable paper constituted the top five forms of trash collected from this location.
- Collection point 2 (kitchen building) produced five 240-liter big garbage bins weighing 199kg. As would be expected, the majority of waste at this location was organic waste.
- Collection point 3 (hostel building) produced nine 240-liter big garbage bins weighing 104.5kg. Plastic bottles, plastic bags, and Styrofoam containers formed the majority waste types collected at this location.

Table 4: Aggregate waste audit data

Type of waste	Weight of Waste from Administration Building (kg)	Weight of Waste from Kitchen Building (kg)	Weight of Waste from Hostel Building (kg)	Weight of Total Waste (kg)	Percentage of Waste Types by Weight
White paper	4.5		1.5	6.0	1.7%
Tissue paper	16.5			16.5	4.7%
Paper cups	1.0			1.0	0.3%
Plastic bottles	3.0		12.0	15.0	4.3%
Plastic sachets	1.5		0.3	1.8	0.5%
Plastic bags	4.3	5.0	27.0	36.3	10.4%
Styrofoam	0.2		12.0	12.2	3.5%
Glass	2.0			2.0	0.6%
Electronic waste	1.0			1.0	0.3%
Tins	1.0		7.5	8.5	2.4%
Non recyclable paper	2.5		-	2.5	0.7%
Organic waste	4.0	189.0	28.3	221.3	63.6%
Cardboard	1.0	5.0	12.9	18.9	5.4%
Other stuff	2.0		3.0	5.0	1.4%
TOTAL	**44.5**	**199.0**	**104.5**	**348.0**	
Number of bins	5	5	9	19	

The different types of waste collected were classified into recyclable and non-recyclable. White paper, paper cups, plastic bottles, plastic sachets, tins, organic waste and cardboard were considered recyclable. Based on this classification, roughly 78% of the waste generated at Ashesi was deemed recyclable, indicating that implementing recycling efforts on campus could markedly reduce Ashesi's ecological footprint.

5.3 Water Project Needs Assessment Findings

5.3.1 Qualitative Results

Interview Findings

Stakeholder interviews revealed the following key goals for the Ashesi campus regarding how water is managed and monitored:

- Manage water use in a way that the Berekuso community is not negatively impacted.
- Provide clean, consistent water sources for the campus in a self-sustaining way, managing quality and safety and ensuring proper operation of water treatment infrastructure.
- Measure and monitor water supply and usage on campus on a regular basis.
- Use water data to develop and implement effective water management policies and inform decision making for resource allocation.
- Manage costs related to water resources.

Overall, three clear themes for Ashesi's water monitoring and management needs emerged through interviews with key personnel:

- ***Reliable data collection and measurement*** through the development of a system that provides tracking of water supply and consumption on campus.
- ***Awareness generation*** to educate the campus community on how Ashesi utilizes its resources to provide a reliable, clean, and safe water supply, and why water conservation is important to the Ashesi community and Berekuso.
- ***Planning and implementation*** of sustainable water management strategies that consider environmental impact on the Berekuso community, with accurate data potentially supporting decision making on which water resources to use, identifying malfunctions such as leaks, and providing reports to stakeholders.

Survey Findings

The preliminary survey of 102 Ashesi community members indicated that the majority of respondents use washrooms most often, and that students are the main consumers of bathing and laundry water usage (Table 5). Roughly half of the respondents drink water on campus, which was a surprising statistic given the many concerns regarding the safety and cleanliness of the water. However, misinterpretation of survey questions might have led to this discrepancy.

Table 5: Primary uses of water by Ashesi community, as indicated by survey respondents.

Purpose for Water Use	Faculty and Staff	Students
Drinking	60.0%	55.6%
Cooking	0.0%	12.5%
Bathing	3.3%	70.8%
Washroom/Toilet	96.7%	95.8%
Laundry Washing	3.3%	56.9%

None of the above options listed	3.3%	1.4%
Other options filled in	10.0%	1.4%

Two-thirds of survey respondents knew where Ashesi gets its water from, but only 11% articulated all three sources accurately. Moreover, 6% of respondents offered answers that were completely inaccurate. This indicated that information campaigns might be necessary to raise awareness about the challenges Ashesi faces to provide water to the entire campus community. Highlighting these difficulties may in turn lead to more conservative use of water resources at Ashesi.

Survey responses related to how water is wasted at Ashesi indicate great potential for reducing water consumption at Ashesi through shifts in water usage habits. The survey indicated that the highest water waste was due to showers, followed by using taps generally and brushing teeth. Washing hands, playful waste, gardening, kitchen use, flushing, and using urinal taps were other responses listed at lower levels of water waste.

Focus Group Findings

In general the focus group interactions reinforced the need for an increased understanding of the campus water systems, how personal actions impact water resources, and communication that the water is safe to drink. Key findings from focus groups are detailed below.

Student Focus Group

Five student participants in the focus group provided information about their perspectives on feasible water management solutions for Ashesi. Although student focus group participants correctly identified campus water sources when asked, they were not aware of the difficulty of maintaining operations of these sources.

Water Waste

Excessive water use while bathing, not appropriately using half and full flush features on toilets, and leaving taps running while brushing teeth were some of the main examples of water waste. In response, education efforts could advise students on how they can individually adapt their water use behaviors to become more conservative. Creating campus norms about how water should be used would infuse the campus culture with acceptable practices in light of the campus' unique and complicated water situation.

Students said that regulating shower usage would be difficult. They said that education and awareness are keys to any initiative to effect behavior change. Students expressed that if peers were aware of Ashesi's water issues and understood the consequences of wasting/overusing water, peers would adapt their behavior. They also suggested that the university threaten to charge or shut water off so that the students would realize the importance of the resource. Students also suggested that water use by contracted cleaners could be regulated.

The water situations on and off campus differ for most students that participated in the focus group. Students acknowledged that water availability in their homes is less reliable and that their parents reprimand them for overuse. Though there was some concern for the water resources, they expressed that university fees entitle them to unrestricted use of water on campus.

General consensus from students was that their peers on campus do not care about water consumption levels. There is a sense that "there will always be water." In this case, correlating the assessment of boarding fees with water monitoring data (expressed in executive management's goals for the project) might help to compensate the university for misuse or at least impress upon students the cost of water.

Drinking Water

Only two of the five student participants during this focus group expressed that they drink water on campus, of which only one trusts the filtration system. The other carries a reusable bottle to refill. Interestingly, the remaining participants acknowledge a lack of trust regarding on-campus water even with a well-defined water quality report. Students acknowledged that there is a "funny taste" to tap water on campus. They reported the campus convenience store as their source for purchasing water.

Water Conservation

The implementation of various tactics to increase conversation about water usage was suggested including visualization and public service announcements. More restrictive methods such as water use quotas were also mentioned. In general, students are cognizant of the need for campus conversation regarding water issues. Efforts that help campus community members to see data in an easily interpretable format seem to be preferred. It is important that students are imbibed with a campus culture regarding water that they will carry with them even outside of campus.

Faculty and Staff Focus Group

The focus group with faculty and staff included questions related to both water and waste issues. Questions during this session related to water issues included:

- Do you think there is a general concern for water on the campus (among students, employees etc.)?
- What behaviors do you feel can realistically be changed among students?
- What is the best way to go about this?
- How would you be willing to help students imbibe a culture of water awareness?

Water Waste

Employees feel that most students have no concern for the water on campus because it is free and their school fees entitle them to waste it. Students also do not trust the tap water for drinking so they purchase packaged water. Because the campus does not house employees, their usage is only limited to drinking (mostly sachet and bottled water), flushing toilets, washing hands and occasional washing of cups/mugs.

Participants all agreed that imposing a moral perspective about water by re-orienting people's mindsets about the scarcity of water and the need to conserve it would go a long way in correcting wasteful behaviors. The national average of 36 liters of daily water use in Ghana per citizen may not be a healthy benchmark with which the school should aspire. The current Ashesi average water usage estimate of 180 liters per day may not be excessive; a lot more information is needed in order to draw conclusions as to whether water is being wasted. The participants felt that Ashesi should focus on knowing exactly how the students are using the 180 liters average per day in order to know which behavior to focus on.

Drinking Water

Most participants in the focus group said they do not drink tap water because of the manganese scare a year ago which broke their habit of drinking tap water. Even though the water is currently safe to drink, most focus group participants said they do not drink tap water; one articulated that she boils the water first before using it. Employees also said the current safety of the drinking water has not been communicated to them. They are also not convinced about the effectiveness of the treatment plant and want to be exposed to the treatment process before their confidence is restored. A number of these faculty and staff also said that they generally do not drink tap water at their respective homes so it has been difficult breaking that habit. Most of them say they would not drink the water even if they received reports/e-mails about the safety of the water. One participant also said that the ban on sachet water at the beginning of the school year got her used to drinking packaged water. When asked what would convince them to drink tap water, some said that proximity to the water source whilst the rest were still adamant to the idea of drinking tap water.

Water Conservation

Participants agreed that purchasing more meters to measure usage volumes and communicating the figures to students might help educate them about their usage and therefore alter behavior. Posters and other visuals showing tips on conservation would also be a good way to change behaviors. The school should also target specific behaviors by communicating to students how they are using water and the best ways to conserve it rather than just telling students to reduce water usage. One participant also said it would be best to disable the water heating system which would make students use less water when showering. One participant said that it would be a good idea to start billing people monthly so they realize how much they are using.

Competitions would also be beneficial in helping students to work on conserving water. The initial capital expense of purchasing meters to measure individual dorm use might be high but the results would be worthwhile in the long run. Participants believe that the process of imbibing an environmental conscious culture is both a policy and persuasion thing. Persuasion alone might be difficult since you have new students who join the school every year and a lot of time has to be spent teaching them conservation practices. For that reason, policies regarding water should be implemented to make sure water awareness and conservation is inculcated in the community.

5.3.2 Determining Water Usage

There is currently no comprehensive data collection of water supply or use at Ashesi. There are four analog meters currently on campus. These are identified in Figure 6. Three meters measure the volume of water in cubic meters flowing to two dormitories, the administration building and the kitchen. In aggregate, these meters track 100% of the water being purposely used on campus (minus Unintended Water Loss or "UWS"). However data from these meters were not recorded in any consistent way prior to the iSTEP 2012 projects. A second concern is because there is only one meter measuring water for both dorm block two and the kitchen, it is unknown how much water these respective units use. In order to derive water use by the kitchen and dorm block two, we calculated the per capita water use from dorm block one and assumed that average for dorm block two, leaving the remainder as kitchen use. The caveat in these calculations is that the dorms are broken down by men and women and if there is any variation in usage patterns by gender these calculations may be flawed. While this approach has clear limitations, we believe we are able get a broad understanding of water consumption by core locations (administration, kitchen, and dorms).

The data from these three meters (excluding the meter used for monitoring the borehole) show that an average 20 m3, or 20,000 liters of water are consumed on campus each day during the summer semester. Also, the months during our data collection (June-August) represent the rainy season in the Eastern Region of Ghana and therefore very little water is needed for irrigation. There are no estimations for water use for irrigation during the dry season. Among the population on campus during the summer (total individuals on campus, including faculty, staff and students), an average of 85.4 liters of water is used per person. Water consumption for those living in the dorm is an average of 224 liters per person and water consumption only in the dorms, per student living in the dorms is 183.7 liters. Figure 7 shows the conclusions of that data collection.

To put this figure in perspective, the average water consumption per person in Ghana is estimated at 36 liters per day and the average use in the United States is 570 liters a day [35]. Comparisons between Ashesi and other similar academic institutions are difficult because each campus has unique geographic water resources and needs and there is a large variance in water consumption based on department composition (technical and research-oriented institutions use substantially more water for research than liberal arts and other non-research based institutions) [36].

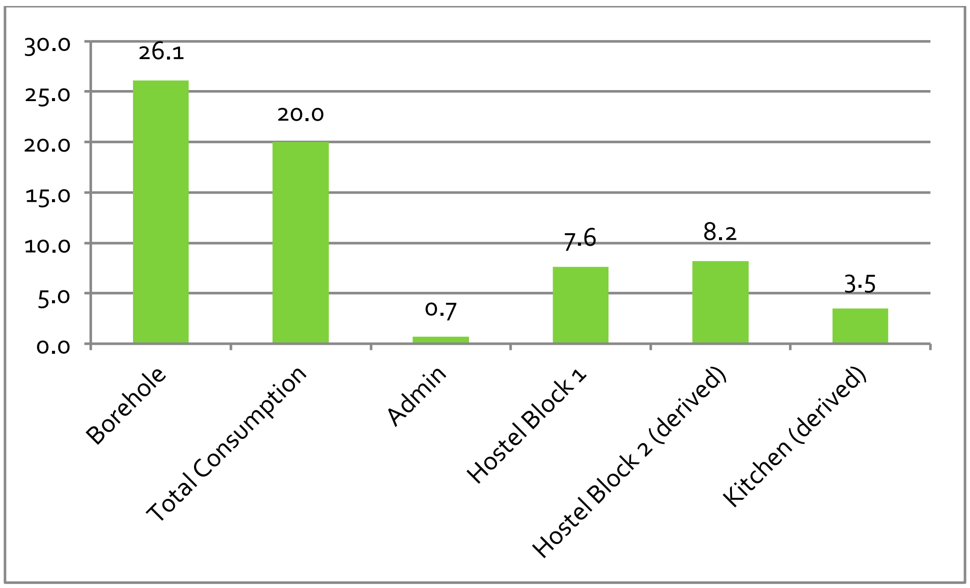


Figure 7. Average daily water used and pumped (liters) from borehole during the rainy season in the Eastern Region of Ghana (June – August)

Dorms use roughly four-fifths of water on campus, followed by the kitchen and administration buildings. The main difference in campus water use composition is irrigation and lab use. At Ashesi, it is currently not possible to measure water used specifically for irrigation because the irrigation pipes are connected at different points between the dorms and the administration building and therefore water used for irrigation is accounted for in the aggregate building block data. However, once the biogas plant at Ashesi is working one meter could be placed on the grey water pipe to capture total irrigation use.

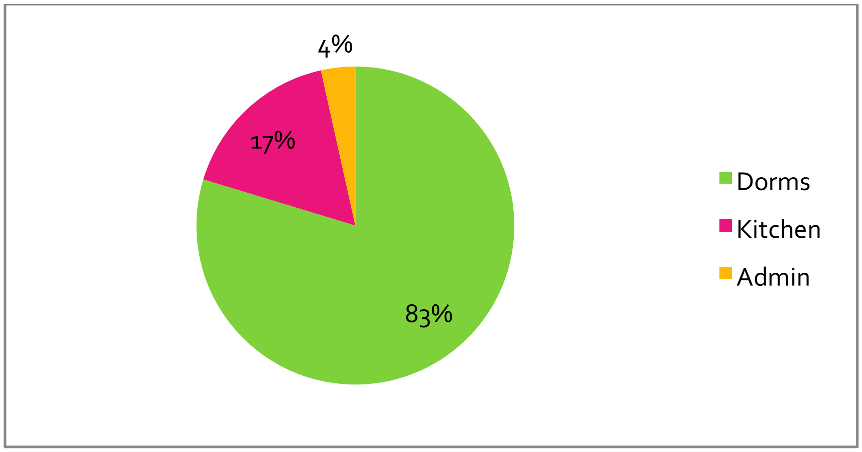


Figure 8. Percent consumption by Admin, Dorms and Kitchen, Ashesi University

5.3.3 Costs Associated with Water Sources

In order to better understand water decision making we also explored the variable costs of water by source. There are three sources of water at Ashesi—from the borehole, rainwater tanks, or purchased water, and the cost for each vary widely. In addition, Ashesi uses a private diesel generator to produce electricity to run the generator to pump water up to campus from the borehole. Currently the diesel costs 1500 GHC a month. Electricity from the main power sources on campus pumps water from the rainwater tanks. Given that the generators operate at 15% power conversion rates and that the rainwater tanks are on campus and do not need to be pumped the 183 meters up the hill, it is estimated that rainwater costs equal 20% of that of costs for water from the borehole. Finally, when there is some system failure water must be purchased.

Based on the experiences of Ashesi's first year at its Berekuso campus, when water is purchased the campus requires five trucks of 3,000 liters of water per day to service campus needs. Each truck of untreated water costs GHC 180, for a cost of GHC 900 total for five trucks of water needed per day. Assuming a month of 30 days this results in a total monthly cost of GHC 27,000. Purchasing untreated water in this way is equal to 90 times the cost of rainwater and 18 times the cost of water from the borehole. If Ashesi needs to purchase treated water, it costs GHC 230 per truck, for a daily total of GHC 1,150. The monthly total of GHC 34,500 for purchasing treated water is 115 times the cost of rainwater and 23 times the cost of water from the borehole.

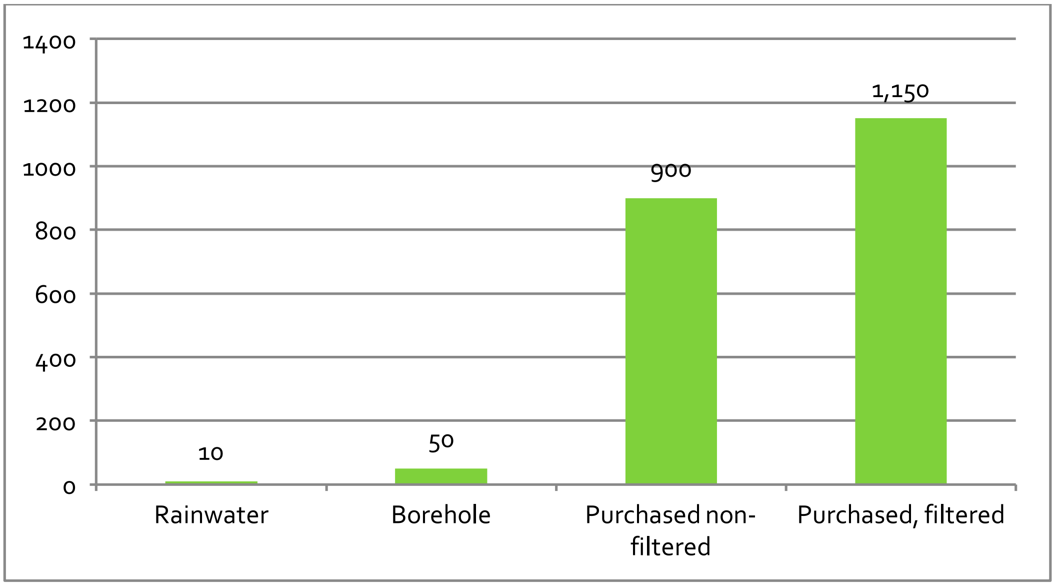


Figure 9. Average per day cost of water by source, based on campus at full capacity (costs shown in Ghanaian Cedis)

6. SOLUTION DESIGN

The needs assessment for both projects highlighted a need for a more effective data collection to monitor water usage and waste accumulation on the Ashesi campus, as well a need to increase awareness among the Ashesi community on issues related to recycling, reducing waste, and conserving water. After some background research and a few brainstorming sessions, it was decided to pursue a technology solution that includes multiple input methods to collect data (both manual entry and automated entry), a centralized database to store the data, and a web-browser based interface to access and visualize the data. As described in greater detail later in this report, posters and social media were used to design and carry out an awareness campaign on campus. In this section we will first describe the developed prototype solution for data collection/storage/visualization and then detail the awareness campaign that was designed specifically for the Ashesi campus.

6.1 Solution for collecting, storing, and visualizing data

6.1.1 Related Technologies

Waste

Information regarding the weight and volume of waste generated on campus is key to effective waste and water monitoring on campus on a regular basis. Needs assessment identified the value of an automated solution with limited to minimal manual intervention. Consequently, we evaluated different technology-based solutions for developing an automated waste monitoring system.

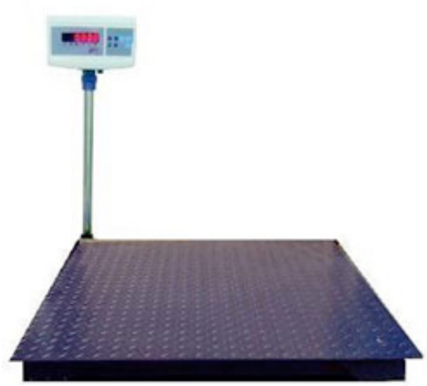
Quantity and volume of waste produced are key considerations for effective waste monitoring. A preliminary analysis of different kinds of technologies, which are in use for measuring weight and volume, can be found in Appendix V. These technologies include Load Cell Based Scales, Basic Digital Weighing Scales, Dial Scales, and Sensors Scales for measuring volume of waste bins, as well as Radio Frequency Identification (RFID), Bluetooth/Wireless for transferring the data.

Weight Measurement

Weighing scales based on load cells are used in a variety of industrial applications for a range of measurements. Load cells are electronic weight measuring sensors which work on the principle of capacitance and resistance. Weights placed/pressure applied on the load cells result in variable voltage which is recorded as a measure of the weight. Typical weighing scales based on load cells are presented in Figure 10.

gure 10. Load cells in use for measuring weight

In addition to load scales, there are a wide variety of digital industrial scales used for measuring weight. Some of the commonly used scales are bench scales, platform scales, floor scales and crane scales (see Figure 11). Platform and bench scales are used extensively in retail, pharmaceutical, logistics and supply chains. These sales have high durability and are built for industrial purposes.



ure 11. Platform

Dial scales are scales for measuring weight with manual readout. Dial scales are used in small and medium enterprises, small scale retail industries and also in scrap/metal weighing industry. Dial scales also find a lot of use in developing countries in weighing scrap wastes and household weighing purposes.

In addition to looking at different types of volumetric scales, we also looked at existing technology for communicating the collected weight information to different end points. The most widely used technology for collating useful waste information are RFID tags. RFID finds its application especially in tracking the trash bins, locating the bins and optimizing routes for trash bin pickup. When combined with enterprise resource planning solutions, RFIDs are an effective solution for autonomously billing customers towards waste collection. A typical RFID system implementation is presented in Figure 12.

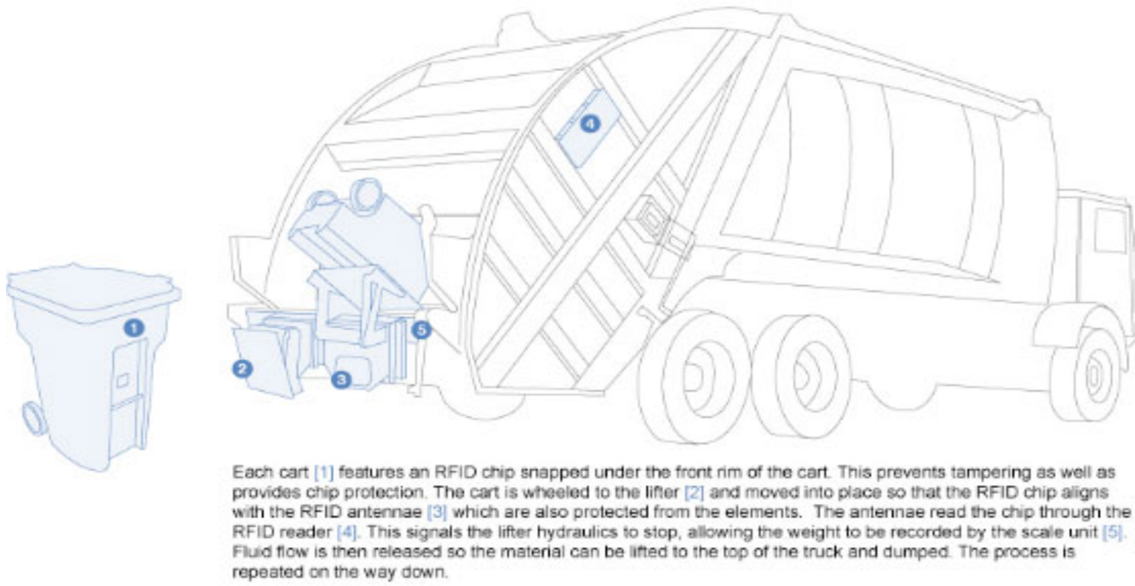


Figure 12. RFID system in use for waste monitoring(Cascade Engineering RFID Systems)

In the illustration presented, RFID tags are attached to garbage bins. When the garbage collection truck approaches the garbage bin information regarding the location of the bin, the customer details are communicated to a RFID reader in the collection truck. A weight sensor on the pick-up platform located at the rear end of the collection truck records the data and communicated this information to the enterprise resource management system located in the collection truck. This information regarding the weight of the bin along with its customer details are then communicated to a server and billing is processed. It has to be noted that the RFID system presented here is an integrated system and is not a standalone system for measuring the weight or volume of the dust bins (Figure 12).

Weighing scales based on Bluetooth/wireless technology find its application in the arena of medical and personal health. Weighing scales that measure body weight and communicate the information to a PC are commonly found in the market (Figure 13). Wireless and Bluetooth technologies are used in these weighing scales for communicating the information recorded to a nearby PC. Most of the weighing scales are battery operated and have limited measuring range. Some examples of Bluetooth/wireless scales are mentioned in Sl.No 2-6 of Appendix V.

ure 13. Bluetooth/wireless scales in use for measuring weight

A comparison of different technologies and analysis of the suitability of scales for the purpose of Ashesi is presented below:

Criterion	RFID	Wireless/Bluetooth	Load cell based	Basic digital weighing scales	Dial scales
Suitable read out – digital/manual		Yes	Yes	Yes	Yes
Suitable connectivity – to a PC	Yes	Yes (limited options for read out of data)	Yes	Yes (limited options for read out of data)	
Measurement capacity (up-to 300 kgs)		No	Yes	Yes	Yes
Scalability	Yes	No	Yes (limited options)	Yes (limited options)	No
Connectivity between different sensors/scales	Yes	No	Yes	Yes (limited options)	No

Volumetric Measurement

Ultrasound sensors can used to measure the water level in tanks or the level of waste in trash bins. Ultrasound sensors measure the distance of the obstacle (based on reflection from the object) from the location of the sensor and can be used to record a measure of the height of trash in the bin by placing the sensor inside the bin's lid. Some of the commonly used ultrasound sensors are presented below (Figure 14).

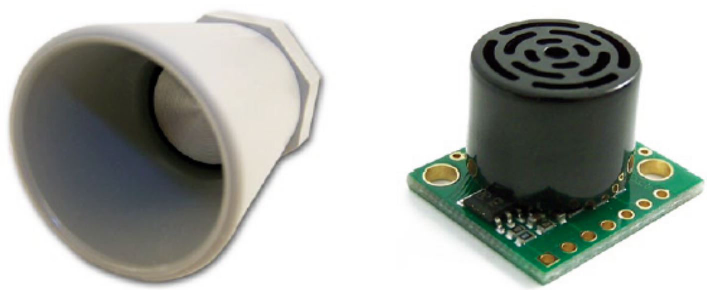


Figure 14. Ultrasound sensors for measuring depth of waste bins

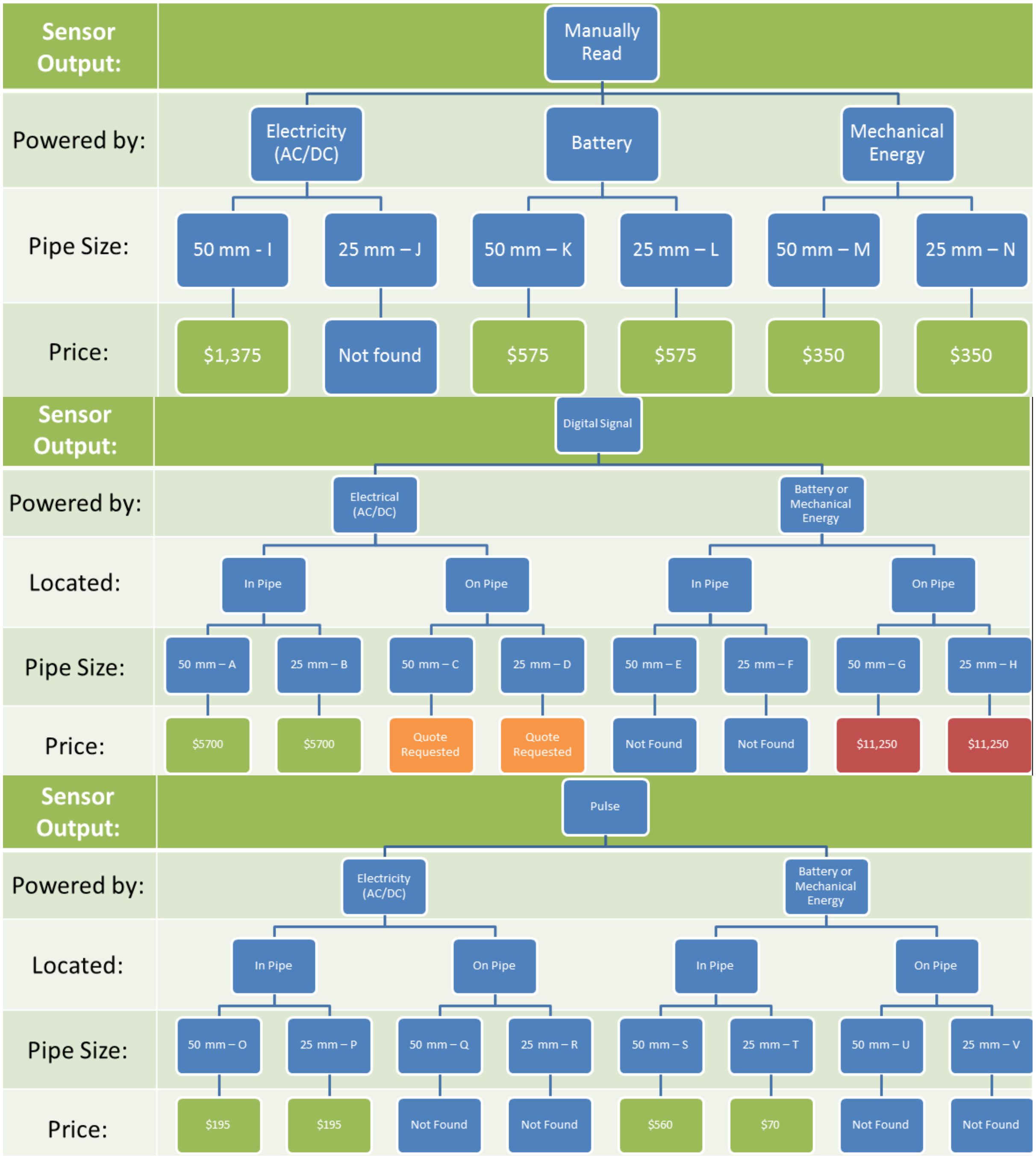
The ultrasound sensors have varied detection range and are used for indoor and outdoor purposes. Applications involving ultrasound sensors connected to smart metering board based on Waspmote kits also find use in waste management projects. A comparison of different ultrasound sensors identified is presented below:

Ultrasound sensor	Application	Range
XL-MaxSonar®-WRA1™	Indoor and outdoor	765 centimeters
LV-MaxSonar®-EZ0™	Indoor	645 centimeters

Water

Below are the summarized results of searching for a sensor fitting each permutation of:

- Signal output (manually read, digital, or pulse output)
- Power supply (battery or no supply needed, or electrically powered)
- Pipe size (25 or 50 mm diameter)
- Location with respect to the pipe (placed on the pipe or installed inside the pipe)



Possible outputs or objectives of the water project have been identified as:

- Measure campus usage: determine daily water consumption data by organization structure (i.e. kitchen, hostels, and administration block)
- Measure hostel behaviors: understand user behavior with regard to water usage (a sample from hostel bathrooms and washrooms)
- Measure rainwater use: identify amount of water used from each original source either rainwater tank vs. borehole

- Monitor tank levels: remotely track levels in holding tanks to optimize rainwater use and reduce man-hours spent checking the levels

For most of these possible systems, data will be collected manually or automatically to a central computer setup. If manual collection is necessary, a convenient form or methodology will be created to regulate how records are inputted to the database. The same database management software that allows inputs will also likely provide graphics and data summaries. The audience with access to this information can be selected to specific groups like operations management, school executives, the entire school, the public, etc. If the software can be created while iSTEP is active, the software will likely be free to the school.

Many of the wireless options expected for these systems are being currently researched. From past experience, we expect each wireless transmitter to cost approximately 250 USD, give or take 100 USD. The central computer setup will likely work as the signal receiver or require another signal receiving product (frequently called a gateway) to be attached.
No specified installation costs have been found for any of these sensors and the contracting costs to Ashesi are not currently known.

Measuring Campus Usage

OPTION A: Automated System	Contracted work required for outdoor power and piping changes, minimal continued labor requirements	**$2600**
OPTION B: Walk-and-Read System	Minimal installation work, requires continuous labor	**$350**

Measuring Hostel Behavior

Assume capital cost of 300 USD per pipe to be monitored. This option requires indoor piping installation and wiring changes.

Measuring Rainwater Usage

OPTION A: Walk-and-read System	Minimal contracted work Extensive continued labor requirements	**$350**
OPTION B: Data Logging, Electrically Powered System	More contracted work Minimal continued labor requirements	**$450**
OPTION C: Automated, Electrically Powered Meter	More contracted work No continued labor requirements	**$500**

OBJECTIVE 4: Identify water levels in holding tanks to optimize rainwater use and reduce man-hours spent checking the levels

Water Level Wireless Solutions

Solar powered, wireless	**$1,900**
Electrically powered, digital output $610 Wireless transmitter required $250	**$860**

For this objective we're actively researching water level sensors that could be easily installed to report wirelessly the fill height in each tank. There will be no manual option for this objective because that is currently what is used, requiring work time from operations management and limiting the efficiency of rainwater harvesting.

6.1.2 Details of Prototype Solution[5]

To improve data collection on water usage and waste generation, a multi component system was developed, which includes a centralized database to store the information, a web browser interface to search and visualize the data, and multiple input systems for both manual and automatic data entry into the system. The entire system is called the Ashesi Resource Tracker (ART) and was built to be easily scalable to manage other types of data (e.g. electricity usage, etc.) in the future but the initial focus would be on tracking water usage and waste levels. The system architecture diagram shown in Figure 15 below highlights the main components of the ART system. Each of the components is described in more detail below.

[5] The Ashesi collaborators contributed significantly to the work reported in this section

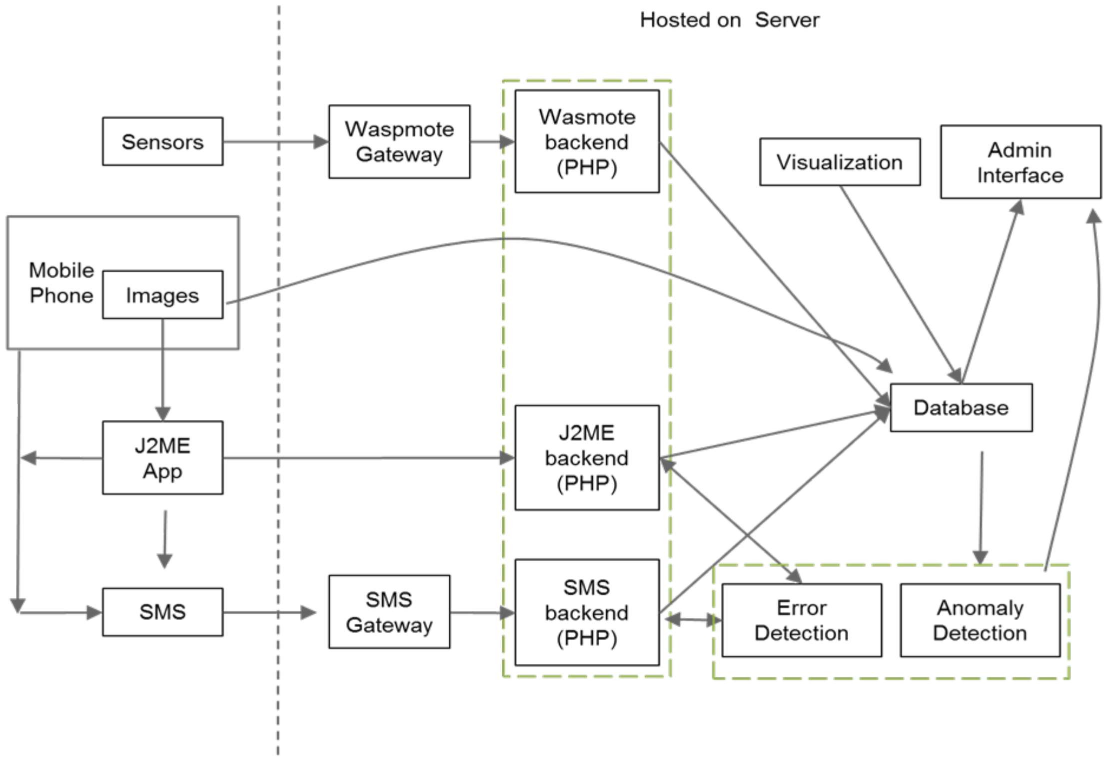


Figure 15. Ashesi Resource Tracker (ART) system architecture diagram

Input Systems

The system is designed to have four possible methods of input: automated sensors, manual data entry through the CMS web interface, SMS routed through a Ghanaian phone number, and a J2ME based phone application. By design, all entries pass through an Error Detection Module (EDM) for automatic detection of common and probable errors. The system's storage is designed to be suitable for any numerical data specified, whether it's waste volume, mass, counts, or another metric.

SMS Input

The first component is an SMS program that allows users to manually input data into a text message on a mobile device and then transmit it to a centralized database where the information is stored and organized. The user must continue daily touring of the meters, but can now send the readings directly into the database via an SMS formatted to include the meter's identifying information (location and ID number). This SMS application can be applied to the collection of data about any measureable substance including waste, electricity, etc.

Figure 16 below graphically outlines the data collection system that incorporates the technology solution developed by the iSTEP team. Its advantages include:

- Less reliant on human intervention
- Features a graphical display of data
- Is centralized: aggregate information can be managed at one location
- Provides historical log of data
- Information available for public use

Its disadvantages are:

- Not completely immune to inaccuracies and human error
- Effectiveness relies on technology adoption into operations personnel's regular duties
- Easily impacted by lack of connectivity (internet, wireless signal)
- Costs associated with: sending SMS messages from various wireless carriers (3-4 pesawas), electricity used by server and computer systems
- Requires skilled individual to maintain system

Figure 16. SMS input data collection system

The SMS input option was developed using a local provider (Airtel) based internet dongle, equipped with a Subscriber Identity Module (SIM) card. The code uses the FrontlineSMS[6] open source software to enables users to send, receive, and manage mobile messages. The formatting of the message does not require any password or passphrase, however, the user's phone number must be authenticated in the database for the data to be considered valid. A properly formatted message simply includes the sensor name 8-character code (displayed on the specific sensor or meter) followed by a delimiter (space) and then the numeric value corresponding to the sensor reading. The SMS input program, written in PHP, is resistant to SQL injection attacks (from a malevolent user), as well as erroneous delimiter usage and entry of extra fields. Refer to Appendix VI for examples of SMS messages and system responses including some examples of detected erroneous entries.

J2ME Phone App Input

To improve on the SMS system, a J2ME phone application was designed to make entries more intuitive and accurate by reducing the likelihood of user error. Any feature phone that supports J2ME applications will be able to have the application installed and used for data collection. The basic UI design is oriented to prevent entry errors. First a user is prompted to specify the sensor being read, and a recent history of recordings is shown as the user inputs their own newest value. Users can also send an image of the sensor or source of information so that Ashesi can maintain a mapped collection of digital images corresponding to user-recorded values.

Automatic Sensor Input

In addition to the manual phone-based data entry solutions, an automatic sensing solution was also developed. Of the different available options surveyed, Libelium's Waspmote products were found to be the best solution due to the availability of various wireless module options, extended battery life (1-5 years projected), and extensive listing of sensors available. Prototyping was done with an ultrasonic sensor, to determine the distance from the sensor to the top level of waste in a bin or the water level in a rain harvesting tank, and with a load sensor, to determine the weight of waste kept in a bin. Flow sensors were also ordered in sizes appropriate for monitoring the kitchen's water use and any hostel shower nozzle. Due to time constraints, these sensors were not fully integrated into the system during this internship. However, some initial prototyping was done with the sensors and details are included below.

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[6] http://www.frontlinesms.com/

In the future development of the solution, automatic sensors will be employed to collect readings and transmit them wirelessly into the database. This digital method will include limited human involvement, lessen human error and cut labor costs associated with the methods currently used to gather the information.

The diagram below graphically outlines the data collection system that incorporates the technology solution developed by the iSTEP team. Its advantages include:

- Not reliant on human intervention
- Immune to human error
- Features a graphical display of data
- Is centralized: aggregate information can be managed at one location
- Provides historical log of data
- Information available for public use

Its disadvantages are:

- Effectiveness relies on technology adoption by operations personnel's regular duties
- Easily impacted by lack of connectivity (internet, wireless signal)
- Costs associated with: attainment of sensors, installation, housing infrastructure, electricity used by server and computer systems
- Requires skilled individual to maintain system

Figure 17. Digital sensor input data collection system

The technical solution developed creates advantages to be experienced by the operations personnel and the entire Ashesi community. With the implementing of the fully automated system that uses a wireless sensor network, operations will not have to deploy personnel to collect data. Additionally, because there is no need for human interaction with the data before it is organized, there will be fewer instances of inconsistencies due to human error. Additionally, a range of Ashesi stakeholders and other members of the public will have access to a catalog of historical data about the institution's resource management.

Prototype Implementation and Experiments

The prototyping involved charging five Waspmotes, testing transmissions to the gateway USB device, testing the range of XBee transmission around campus, testing the two flexible solar panels, and receiving and transmitting signals from a sensor. The final step of the process involved reading XBee transmissions from the gateway into the iSTEP database for storage. Unfortunately this final step was not completed during the internship period.

Brief range tests were done from significant points around campus to the library, a location regarded as difficult to transmit to due to its location and thick structural elements. In Figure 18 below, the green lines indicate successful transmission and red lines indicate failed transmissions. The blue stars are the locations of analog water meters on campus that respectively indicate the likely installation locations of future digital meters.

Figure 18. Waspmotes deployed at the different sections of the environment

Content Management System (CMS)

In addition to collecting data from the sensors, an effective solution involves a well-defined data management component. Both the water and waste projects require a methodology to easily collect and input information, a centralized location to store the information, and a reporting tool to summarize information in a concise way. Towards that, we developed a web-interface CMS for a storage database with a variety of data input sources. After listening to the needs of the university community, it was established that further resource tracking may be useful in the future, such as monitoring electrical expenditures. With that in mind, the CMS was designed to be expandable, with some additional development work, to record information about almost any campus resource.

The CMS includes an "admin" interface that allows users to manage data collection locations, add and manage sensors, manage system users and view all readings. The system will also check for anomalies in the data, which may be caused by human error. The CMS also includes a publicly accessible web-based user interface which provides access to aggregate data in the form of bar and line graphs which represent trends in water usage or waste accumulation. Stakeholders and anyone with access to the Internet will be able to use this program.

The decision to have a web-interface was based on the benefit of not having any setup requirements (other than an internet browser), which custom client-side software might have entailed. The CMS allows the team at Ashesi to easily manage the database information, specifically access control for users, sensors, locations, and data points. Further, it provides a comprehensive view of the data records and allows for the results of the EDM to be analyzed and individually decided on by approved users.

After a brief online search of available open-source CMS tools, CakePHP[7] was chosen as the platform primarily due the team's familiarity with the tool and the fact that it included convenient wrappers for much of the required functionality. The CMS's main functional requirements are

1. Add and edit users and manage their permissions to the manual input options
2. Manage past data points, especially with regards to fixing input errors
3. Create publically available graphic visualizations of data selected by time, location, and sensor; set links to and allow uploads of awareness information, posters, and related contact information
4. Allow specified users to download the raw data used to create graphics

Database Structure

The internal database structure for any resource records has the following columns specified:

Column	Description	Type	Typical Entry
Id	The primary key for this data entry	Integer	16
Uid	The user ID, a reference to the primary key of the responsible user (if manually input)	Integer	39
sensor_id	Reference to primary key of sensor/metric used	Integer	46
location_id	Link to primary key of the location of the data source on campus	Integer	2
Value	The specific data recorded in each entry	Double-precision Float	45.6
entry_source	Specifies the form of input that relayed the entry	String	CMS
db_entry_date	Timestamp of entry to the database	Timestamp	2012-07-19 09:58:19
value_date	Timestamp of when the value was initially observed	Timestamp	2012-07-18 13:29:14
active	Binary specification as enabled or disabled for use in data	Integer	1
Flag	Flag indicating errors detected by EDM (if any – zero indicates no error)	Integer	0
anom_flag	Flag indicating errors detected by ADM (if any – zero indicates no error) [not yet implemented]	Integer	0

As mentioned in the table above, each manual entry is linked by User ID to the respective **user profile** with the following columns:

Column	Description	Type
User ID	The primary key for this user profile	Integer
Password	User-defined entry code	String
Email Address	Primary contact method used for user authentication	String
First Name	User's personal identifiers	String
Last Name	User's personal identifiers	String
Phone Number	9 digit number, assuming +233 for Ghana	Integer

[7] http://cakephp.org/

Date	Timestamp of when user profile was added	Timestamp
Activity Status	Binary specification as enabled or disabled for access to database input	Integer

The data points and sensors are each linked by Location ID to the table of locations on campus with the following columns:

Column	Description	Type	Typical Entry
Location ID	The primary key for this location	Integer	2
Name	Publically recognized title of a campus area	String	Administration
Short Code	Three character abbreviation of name	String	Adm
Description	Space to specify bounds and meaning of location name	String	Founder's plaza buildings (offices, lecture halls, and gardens)
DB Entry Date	Timestamp of entry to the database	Timestamp	2012-07-19 09:58:19
Activity Status	Binary specification as enabled or disabled for use in recording data	Integer	1

Each source of data on campus is classified for this project and in the database as a "sensor", be it manually entered or via an automated sensor. These sensors are labeled with alphanumeric codes designed to be understood by the computer systems and human users alike. The resource being measured and the campus location of the sensor are abbreviated to unique 3 character codes, and concatenated with a two digit number that differentiates between any sensors common to those identifiers. For example, a waste (Wst) bin located in the campus hostels (Hos) could be titled WstHos04. The details of **each sensor** are stored in another table with the following columns:

Column	Description	Type	Typical Entry
Sensor ID	The primary key for this sensor entry	Integer	46
Location ID	Link to primary key of the location of the data source on campus	Integer	2
Category Code	Three digit code to abbreviate the category of data entered	String	Wst
Sensor Number	The two digit number used to differentiate sensors with common identifiers	String	01
Category	The category of resource being measured	String	Waste
Activity Status	Binary specification as enabled or disabled for use in recording data	Integer	1
DB Entry Date	Timestamp of entry to the database via the CMS	Timestamp	2012-07-09 09:52:17

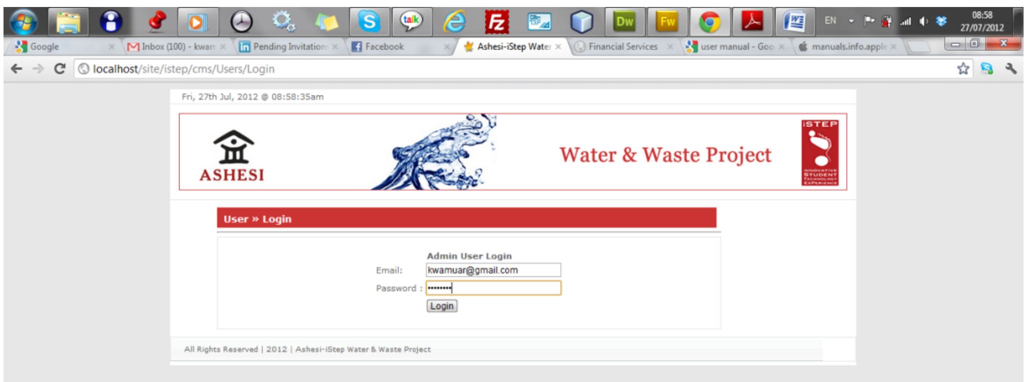
Because the input systems need to interface with the database regarding sensors that are known by their concatenated sensor code, a **view table** of the sensor data was created with the following columns:

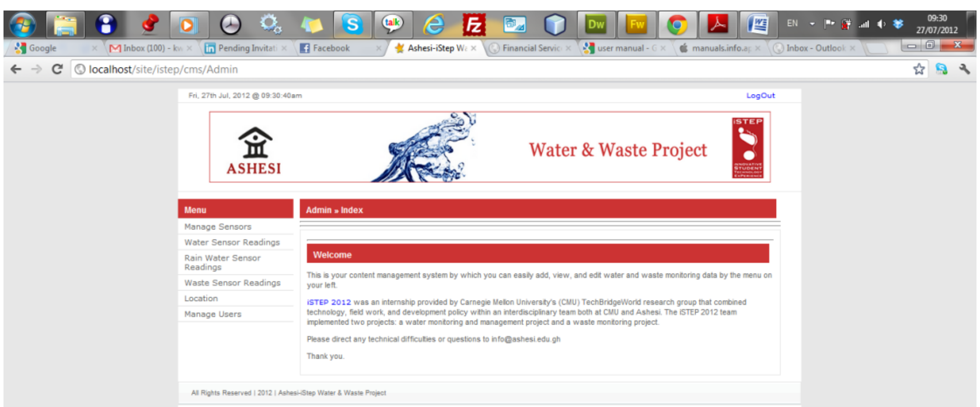
Concatenated Sensor Specifications Table Structure: istep_db > sensor

Column	Description	Type	Typical Entry
Sensor ID	The primary key for this sensor entry	Integer	46
Location ID	Link to primary key of the location of the data source on campus	Integer	2
Sensor Name	The 8 character concatenated code name	String	WstAdm01
Category	The category of resource being measured	String	Waste
Activity Status	Binary specification as enabled or disabled for use in recording data	Integer	1
DB Entry Date	Timestamp of entry to the database via the CMS	Timestamp	2012-07-09 09:52:17

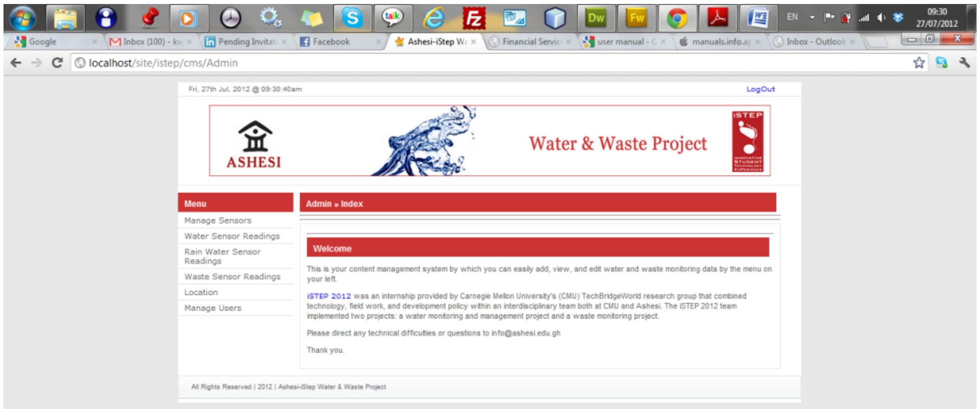
Admin Interface and Visualization

In order to visualize the collected data and to provide ease of operational controlled, we developed a web-based user interface. The developed interface allows approved users to login using their personal credentials to see a brief introduction to the system.

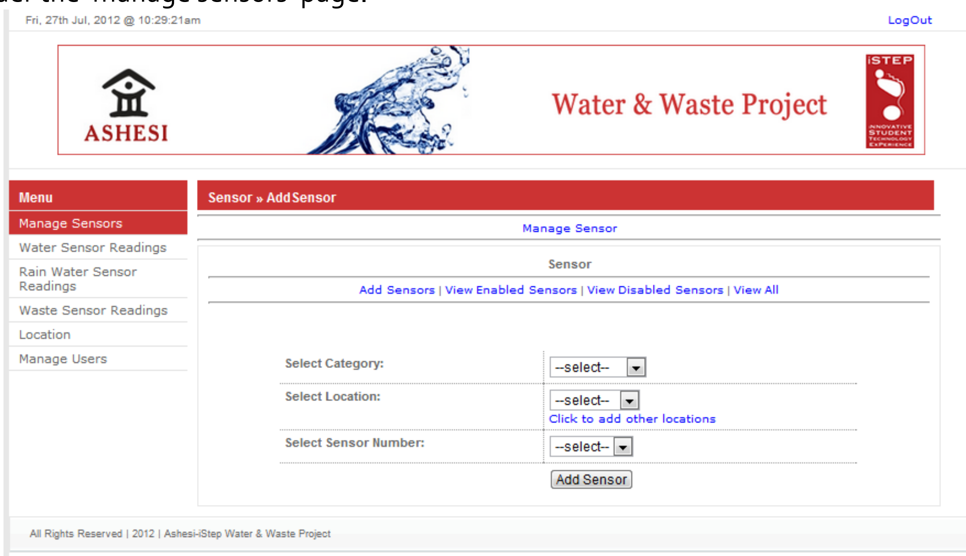




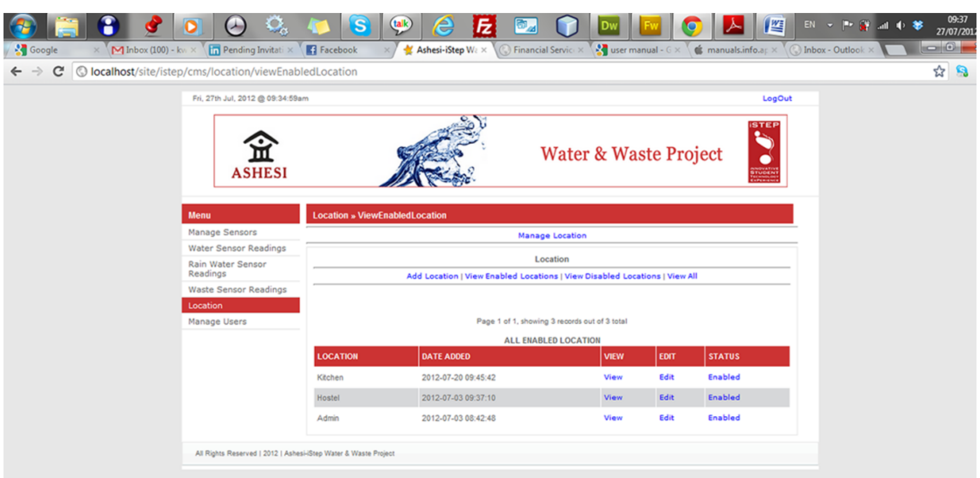
Data can be added by selecting the appropriate category's data entry page from the menu on the left-hand side.



When the infrastructure of tools used to measure campus resources changes, they can be added as sensors under the 'manage sensors' page.



Specific locations of interest an also be added via the 'manage locations' page of the CMS.



In the case of input errors that are noted by a human user or the Error Detection Module, a flag value will be given to a data entry. These notable data entries can be reviewed and manually handled. An acceptable entry can be returned to a flag value of 0, and erred entries can be set to active status of 0 so that they are no longer used in visualization and reporting.

6.1.3 Strategy for Waste

Based on the analysis of the different technological options, we have identified load cells for measuring the weight and ultrasound sensors for measuring the volume of the dustbins as the appropriate technology for waste monitoring at Ashesi University. In this section, we further detail the implemented solution

Measuring Weight

Load cells will be connected to the Libelium Smart metering pro board (shown in Figure 19 below) which will be installed on a Waspmote. The Waspmote will be powered by a battery and the readings will be noted through the Waspmote gateway. AMS load sensors from Hanyu with the following specifications have been selected [37]:

Rate load	50, 100, 150, 200, 250, 300, 500, 600kg
Sensitivity	2.0±0.1mv/V
Accuracy grade	0.02%F.S
Nonlinearity	±0.02%F.S
Recommended excitation voltage	+9V ~ +12V
Operation temperature	20°C ~ +60°C
Protection	IP-65

Table 6. Technical specification of AMS load sensor

The load cell will be excited through power input from socket 9 of the Smart metering pro board. An image of the corresponding socket (socket 9) on smart metering pro board for connecting the load cell is given in Figure 19.

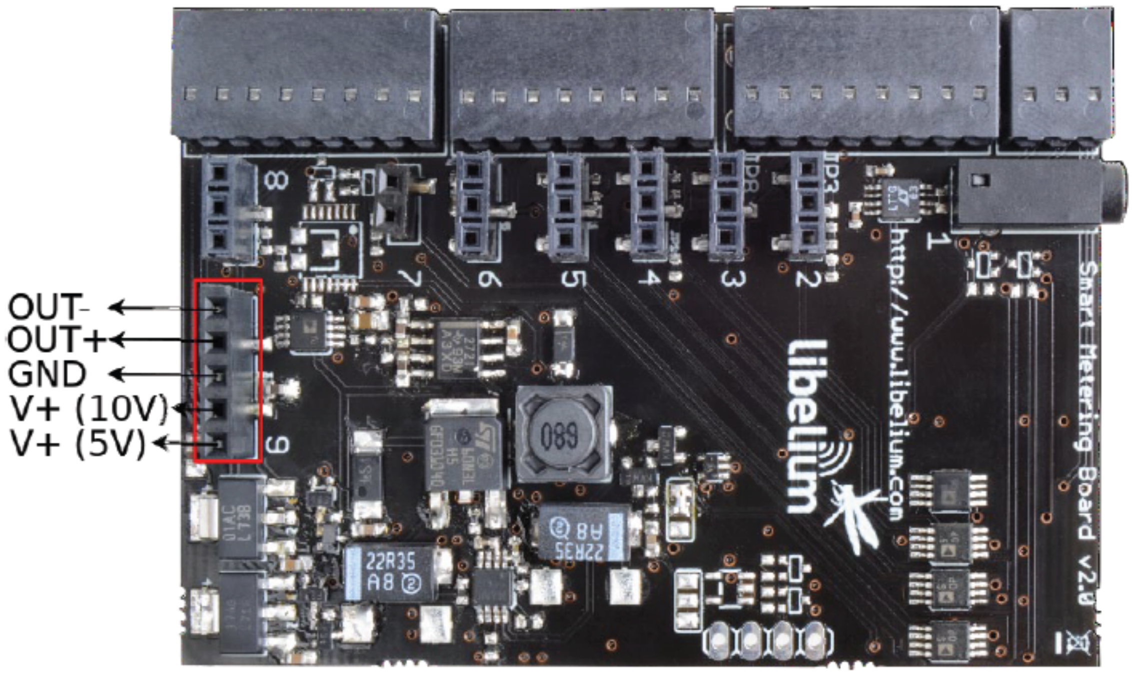


Figure 19. Smart metering pro board with socket 9

Based on the weight of the load, the sensor records the voltage and communicates this information through the gateway to the database. A sample output of the output voltage vs. weight of the load is given in Figure 20 [37].

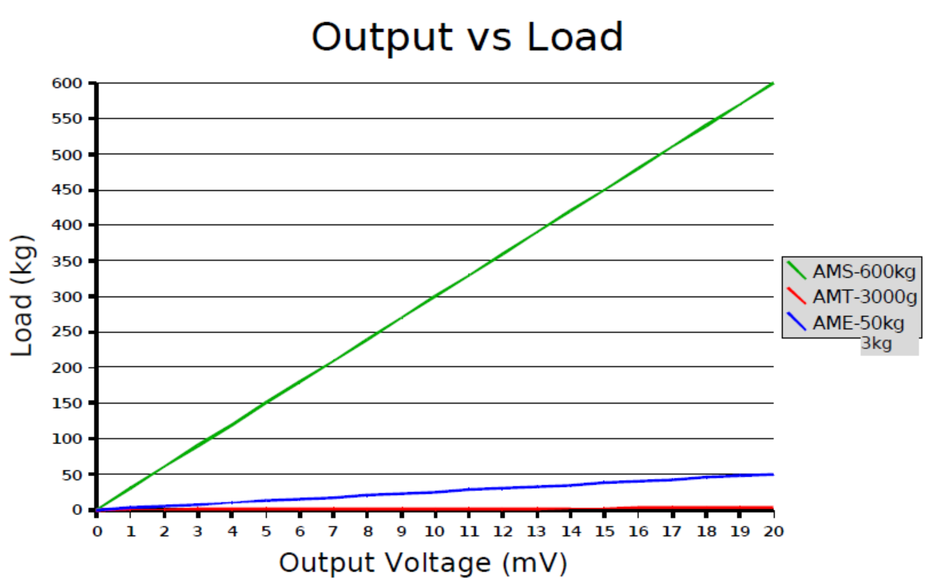


Figure 20. Output of AMS load cell

The surface area of AMS lead cells selected is small compared to the floor size of the dustbins. In order to accurately measure the weight of the dust bin we plan to use two load scales. A wooden plank will be placed on the load scales and the dustbin will be placed on the wooden plank at the center of the two load scales. A sample illustration of the prototype is presented in Figure 21.

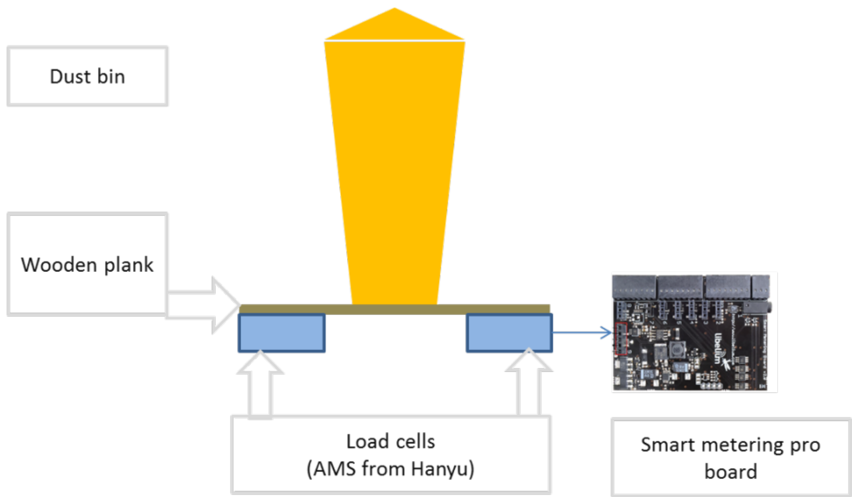


Figure 21. Sample illustration of use of load cells. Load cells have been identified as the appropriate technology for waste monitoring (weight measurement) at Ashesi University.

The whole setup will be placed below a select bin in the hostel and the readings will be recorded through the gateway located in the academic building.

Measuring Volume

An ultrasonic sensor will be connected to the 'Libelium Smart metering pro' board which will be installed on a Waspmote. The Waspmote will be powered by a battery and the readings will be noted through the Waspmote gateway. The XL-MaxSonar-WRA sensor with the following specifications was selected [37]:

Operation frequency	42kHz
Maximum detection distance	765cm
Maximum detection distance (analog output)	600cm (powered at 3.3V) - 700cm (powered at 5V)
Sensitivity (analog output)	3.2mV/ centimeters (powered at 3.3V) – 4.9mV/ centimeters (powered at 5V)
Power supply	3.3 ~ 5V
Consumption (average)	2.1mA (powered at 3.3V) – 3.2mA (powered at 5V)
Consumption (peak)	50mA (powered at 3.3V) – 100mA (powered at 5V)

Table 7. Technical specification of XL-MaxSonar-WRA sensor

The ultrasonic sensor will be excited through power input from socket 2 and 8 or sockets 3 and 6 of the Smart metering pro board. An image of the corresponding socket (socket 2 and 3) on smart metering pro board for connecting the load cell is given in Figure 22 [37].

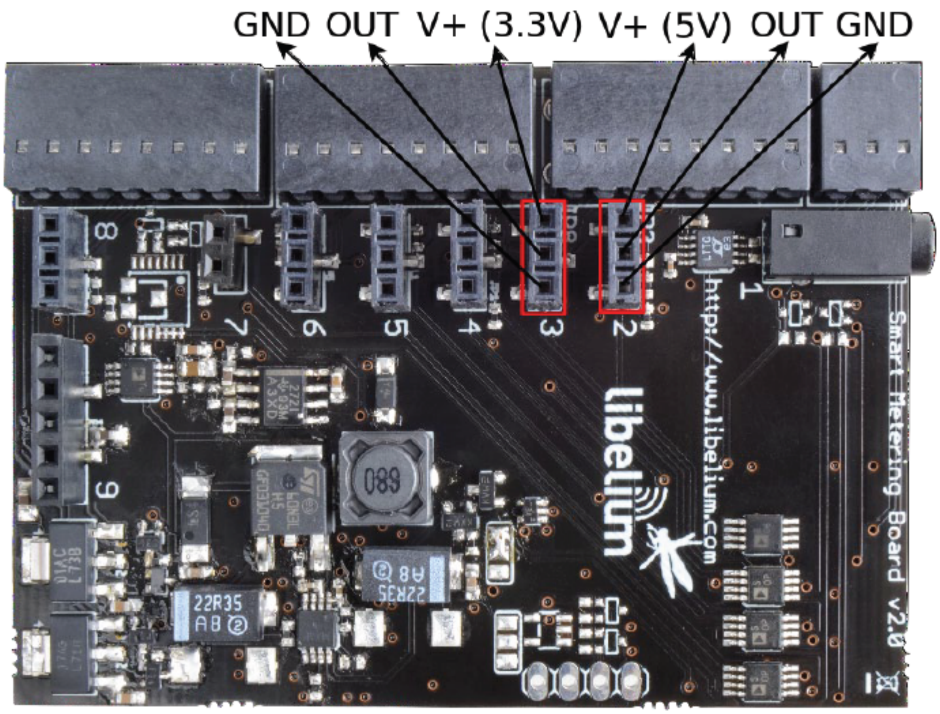


Figure 22. Smart metering pro board with socket 2,3

Based on the surface level of the contents in the bin, the sensor records the voltage and communicates this information through the gateway to the database. An illustration is presented in Figure 23 [37].

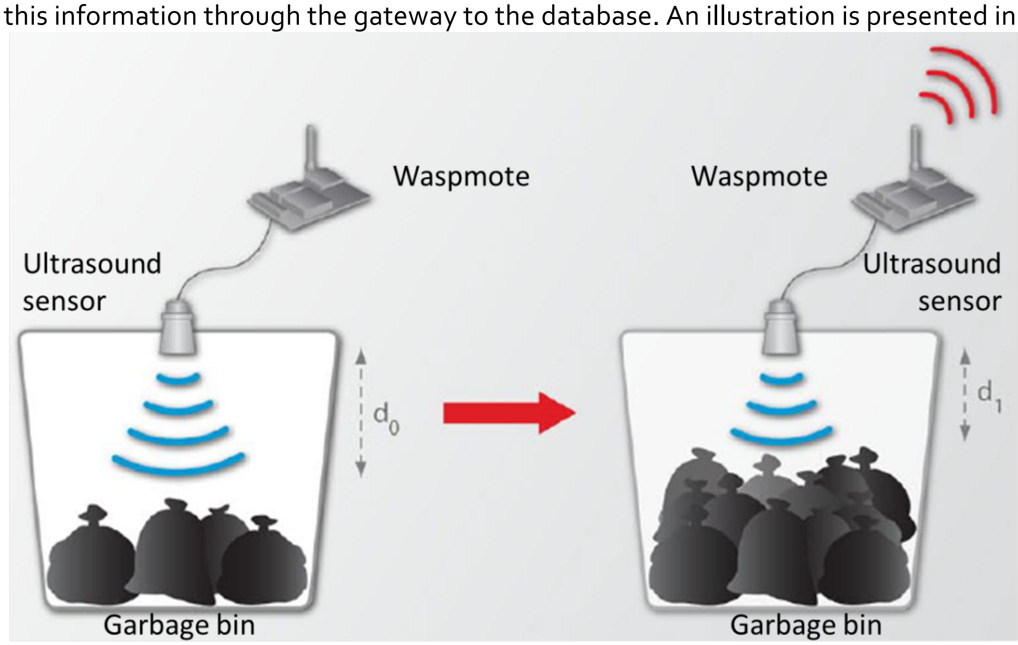


Figure 23. Sample illustration of functioning of ultrasound sensor. Ultrasound sensors have been identified as the appropriate technology for waste monitoring (volume measurement of dustbins) at Ashesi University.

A special marking will be made at the center of the top lid of the bin for placing the sensor. The whole setup will be placed on the top lid of a dust bin in the hostel and the readings will be recorded through the gateway located in the academic building.

6.1.4 Strategy for Water

Early within the needs assessment it became clear that any solution should increase the ability to store aggregate water data. A core interest amongst stakeholders and observation of the team was the difficulty of maintaining up-to-date data on water use without an easy to use, and if possible, automated system. While Ashesi has several analog sensors, these have not been used to collect data. To that end, we decided that digital sensors would need to be installed, along with some form of a content management system (CMS) to incorporate the data.

Ultrasonic Flow Meters vs. Pulse Meters

Originally, our research pointed us towards to potential benefit of a solution using ultrasonic flow sensors (UFS). UFS are a leading technology because they can measure a plethora of data, including flow rates from an ultrasonic pulse, and are clamp-on, meaning they can be moved from pipes of different sizes. Despite technological superiority of UFS, they are expensive (ranging from USD2,500-11,000), and require technical support for both maintenance and managing the data output.

An alternative technology is a pulse sensor that only measure water volume. Pulse sensors must be installed within a pipe, similar to analog meters, and thus are fixed. Pulse meters are also substantially cheaper (ranging from USD70-500). For Ashesi, we concluded that flow rates were not a primary concern, as they are important in piping systems that either have volatile pressure levels or where consistent pressure is a core concern (such as in medical equipment). As we were developing a prototype system with the end-goal of scalability, a simple, fixed pulse sensor would meet our initial needs at a fraction of the cost. Consequently, we focused our sensor decision-making around pulse meters.

Wired vs. Wireless Sensors

The water meters at Ashesi are located outdoors at significant distances (more than 6 meters) from the nearest building. Running electrical lines to power each sensor would demand substantial work and increase the potential points of failures. On the other hand, depending on use, batteries from digital sensors deplete rapidly, increasing maintenance costs and time. After exploring numerous electricity consumption scenarios, we believe the right balance is that of a battery powered system that can be overcome by constraining the rate of transmission to once a day. In other words, the system would store real-time data but only be accessed once per day by the centralized content management system. Moreover, we believe in the future a sustainable system of battery-powered (or solar) sensors would be a scalable solution.

Wireless Water Monitoring Sensors

The final water monitoring system at Ashesi will include a number of sensors ranging from small meters inside individual washrooms, to sensors inside rainwater tanks. As part of the prototype solution, we deployed a set of Waspmote sensors at a few critical data collection points across the campus. Libelium's Waspmote products were selected due to the various wireless module options, extended battery life (1-5 years projected), and extensive listing of sensors available.

6.2 Strategy for Increasing Awareness

Focus groups conducted with students, faculty and staff, helped the team to gain a clear understanding of reasons behind certain behaviors. The various issues identified from these sessions were highlighted and various proposed solutions were suggested for each of them with respect to the different kinds of waste. This can be seen in this section.

This section is divided into two parts; waste and water. The first part includes the various methods or strategies that can be used to address the situation of waste monitoring in Ashesi; in particular, recycling measures. A pilot awareness campaign was conducted within a 2-week period. The result of this pilot awareness campaign is seen at the end of the waste section.

The second part addresses the issue of water management and conservation efforts. These strategies were based on feedback received from focus group discussions of students, faculty and staff. As highlighted in the details below, various stakeholders were taken into account in preparing this document. Details of the issues identified and their proposed solutions for each kind of waste are presented in the sections below.

6.2.1 Specific Approach for Waste Project Awareness

The data gathered from focus group meetings (5.2 and 5.3) was analyzed and a detailed awareness strategy was prepared based on identified issues associated with different kinds of waste. Details of the issues identified and the proposed approach for each kind of waste are presented in the following sections. More detailed recommendations for each kind of waste can be found in Appendix VII.

Polythene/plastic bags

Polythene/plastic bags contribute about 10% of the total waste collected on campus and is almost exclusively generated from the stores and kitchen on campus. Though options like use of paper bags and recyclable bags are possible the following issues were highlighted as the key causes for the use of plastic bags on campus:

1. Limited reusability of the plastic bags which are used currently (because of low quality)
2. Practice of using plastic bags for all purchases (irrespective of the requirement/necessity)

To address the above challenges we proposed the following approach:

1. To encourage reusing of the plastic bags:
2. To encourage reduction in use of plastic bags:

Water Sachets

Water sachets (Figure 24) contribute about 1% of the total waste collected on campus. Even though the campus has a water purification system and the quality of water is tested on a regular basis the following issues were highlighted as the key causes for the use of water sachets on campus:

1. Limited awareness about the water treatment system (both among students and faculty, staff)
2. Limited awareness about the water testing system and communication of results
3. Lack of water bottle filling stations (cultural sensitivity associated with filling water bottles in kitchens and bathrooms)
4. Lack of water cooling systems (leading students to buy pre-cooled water sachets/bottles from the campus stores)

To address the above challenges we propose to undertake the following approach:

1. To increase awareness about the water treatment system:
2. To increase awareness about the water testing system:
3. Increase bottle filling stations:

Styrofoam

Styrofoam contributes about 4% of the total waste collected on campus and is almost exclusively generated from the kitchen/catering activities on campus. Though options like use of plastic boxes and paper boxes are possible the following issues were highlighted as the key causes for the use of Styrofoam on campus:

1. Plastic boxes – though they are easy to use the boxes have to be cleaned after use
2. Limited options available other than Styrofoam (focus groups participants indicated that Ghanaian food is oily and so paper boxes may not be a suitable option)

To address the above challenges we proposed the following approach:

1. To increase usage of plastic boxes
2. Ban Styrofoam on campus completely

Paper

Paper contributes about 2% of the total waste collected on campus and is almost exclusively generated from the academic activities on campus. Most of the paper is generated from printing activities and notes/books from the students. The following issues were highlighted as the key causes for the use of excess paper on campus:

1. Printing reports and documents is seen as a backup (due to unreliable internet connection)
2. Limited options for double-side printing (printing is almost exclusively single-sided)

To address the above challenges we propose to undertake the following approach:

1. Encourage use of electronic documents
2. To increase options for double-side printing

Electronic Waste

E-waste (consumables like toners and ink cartridges) contributes about 0.4% of the total waste collected on campus and is almost exclusively generated from the academic activities on campus. Most of the e-waste is generated from the use of IT equipment on campus. The following issues were highlighted as the key causes for the disposal of e-waste:

1. Limited options for recycling/market for recycling
2. Lack of separate e-waste policies for collection and disposal

To address the above challenges we propose to undertake the following approach:

1. Encouraging reduction in e-waste:
2. Encouraging recycling of e-waste:

Plastic Bottles

Plastic bottles contribute about 4% of the total waste collected on campus. Most of the plastic bottles are generated from the kitchen and the stores on campus. The following topics were discussed during the focus group meeting:

1. There is no recycling of plastic bottles on campus
2. Students expressed interest in source segregation and recycling of bottles

To address the above challenges we propose to undertake the following approach:

1. To increase recycling through source segregation:

Cardboard

Paper contributes about 5% of the total waste collected on campus and is almost exclusively generated from the stores on campus. Cardboard boxes are being reused on the campus. The following are some of the commonly uses found on campus:

1. For collection of trash related to gardening
2. For collection of food waste from the catering area of the kitchen in academic building

To address the above challenges we propose to exploring options for reusing of cardboard boxes.

Tissue paper

Tissue paper contributes about 5% of the total waste collected on campus and is almost exclusively generated from the washrooms on campus. The following issues were highlighted as the key causes for the disposal of tissue paper:

1. Though tissue paper can be flushed in the water closet (WC), students and staff have mixed understanding about the same
2. Instances of wasteful use of tissue paper are also noted by the operations personnel

To address the above challenges we propose to undertake the following approach:

1. Encouraging flushing of tissue paper:
2. Discouraging wasting tissue paper:

6.2.2 Pilot Awareness for the Waste Project

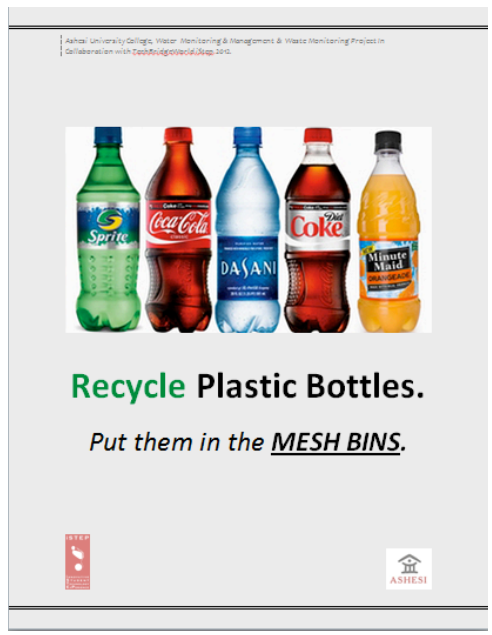
In order to understand the stakeholders perception and response to the awareness programs being planned a pilot awareness program was implemented during week 7 and week 8 (09 July 2012 to 20 July 2012) of the iSTEP 2012 internship. Different focus areas for pilot awareness were considered and plastic bottles and tissue papers were selected as the key focus areas for the pilot awareness.

Plastic Bottles

The source segregation separate bins for collecting the plastic bottles were placed at select locations in hostels, academic and kitchen building. Specially designed bins with circular openings were prepared. For the purpose of pilot implementation mesh bins (locally used as laundry bins) were used and a circular hole was made on the top of the bin to induce stakeholders to place only bottles in the bins. A mesh bin with the circular opening is presented in the image below:

Figure 26. Poster for recycling plastic bottles

Figure 25. Mesh bins for collecting the plastic bottles with the circular hole on top



10 bins (5 bins in the academic building and 5 bins in the hostels) were placed during week 7 of the iSTEP 2012 internship. Posters clearly marking 'Recycle plastic bottles. Put them in the mesh bins' were pasted on the bins and also in select locations across the campus.

For the purpose of data collection a basic template was prepared and shared with the operations personnel in-charge of the cleaning staff in academic and kitchen buildings. All the bins were marked with a location code and an ID number and the data was collected and recorded daily during weeks 7 and 8.

An evaluation of the all the mesh bins placed revealed the following observations:

- All the bins were upright, fixed properly and located in the same location as they were placed (despite wind and rain during the week).
- The labels placed on the bins were intact and clear.
- Most of the trash placed in the mesh bins were plastic bottles. However in two bins, instances of tissue paper and books were observed in the mesh bins.
- Instances of plastic bottles being placed in bins other than mesh bins were observed in three locations. A closer observation revealed that plastic bottles are placed in other bins where mesh bins were not in close proximity.

Tissue Paper

In order to encourage stakeholders to flush the tissue paper and to not waste tissue paper, posters were designed and placed on the back of the door in all WCs across academic building and hostel buildings in use. Existing posters, which are cluttered and having a lot of data, in some of the WCs from the academic building were replaced with new posters developed for the pilot awareness campaign, which contained clear and concise text.

Figure 27. Old posters in use in the WCs

The posters were printed on stickers in order to facilitate placing them on walls and doors. However, as the posters were designed for pilot implementation push pins were used for placing the posters. In some cases cello tape was used for placing the posters (due to inadequate push pins for all the locations).

Figure 28. New posters for tissue papers

An evaluation of the posters (18 out of total of 118) placed was conducted and the following observations were noted:

- All the posters evaluated were still affixed (despite wind, humidity in the wash rooms).

- All the posters fixed with push pins were in good condition.
- All the posters fixed with cello tape were curled (due to humidity and also peeling off of the cello tape).
- An instance of a poster falling off the door was also observed in one location.

6.2.3 Specific Approach for Water Project Awareness

Outline for a Water Use Competition amongst Ashesi Dorms

About 70% of the Earth's surface is covered by water, but only about 1% of the water on Earth is consumable freshwater. The rest is found in oceans and glaciers and is unavailable for use by humans. Research has indicated that, Global water demands will increase by 40% in the next ten years. Consequently, by 2025, two-thirds of the world will live under conditions of water scarcity [39]. As water becomes limited, water conservation is essential. At Ashesi University College, we propose that in a bid to encourage students to conserve water, the school administration in conjunction with the dean of students affairs run a competition for the students who live in the campus dorms. This is because; adding a competition aspect to an activity motivates people to participate more actively. But giving them with an incentive tends to keep their interests and encourages them to focus more on the competition. An example of a competition can be seen below.

Competition Title: "Save Ashesi's Water" (SAW)

Objective: To encourage students to conserve water in order to help Ashesi manage its water resource. The aim of the competition is to spark important dialogues among the students about water conservation and environmental stewardship.

Strategy: Use sensors that currently exist on campus to track the amount of water being used by resident students in Dorms (Block A against B). This competition could have different categories; the overall reduction in the amount of water used per student and the overall percentage reduction per block. This is to highlight to the students, how much water they have been able to reduce individually and how much water usage, they have reduced as a Dorm block. "Win or lose", this water conservation challenge between Dorm Blocks would be a great initiative in making all students more mindful of the water conservation drive by the school.

Methodology: This would be a semester long competition. Therefore, during the first week of each semester, the competition would have to be announced to the whole student population and the strategy explained to them thoroughly.

At the beginning of the first week of the competition, declare the meter readings for both dorm blocks. This could be sent via mail to the entire student body, faculty and staff. A notice board can then be put up in the Founder's Court with these readings for all to see. Waiting until the end of each week to give the Friday reading and declare the results would create some suspense among students. However, the readings could be written on the board every other day or twice a week to help students keep track of the amount of water they are using and to encourage them to develop strategies to conserve water in their individual dorm blocks. Below are two different scenarios that could arise as a result of students' participation in the competition and their instincts to win.

Scenario 1: George passes by the Founder's court and sees that the notice board has been updated. He realizes that within 2 days his dorm block has used more water than their competitors. So he quickly goes to the lab and does a bit of research on water conservation and puts it at vantage points in the hostel to draw the attention of other students.

Scenario 2: At the end of the week, the results are declared and dorm block 2 realizes a little too late that they used more water than block one. Going forward, they come together as a block to device strategies to conserve water.

Clearly, these two scenarios show what could happen depending on the timing of feedback given to students. But then again, it is up to the ASC and the office of the Dean of students' affairs to decide what would be ideal for Ashesi's student population. However, in both cases, Ashesi could also use bulk SMS to send the results of the competition as well as the timely updates.

Benefits of Competition: This kind of competition comes with a number of benefits, not just to the community members of Ashesi University College, but also to the environment. These benefits include:

- **Economic** – Currently, the campus is paying so much to pump and treat water for use by the community. Water conservation practices would help the school reduce the amount of gallons per water used in a school year. This means, more savings for the school. A part of this savings could be used to reward the winners of the competition.

- **Environmental** –Clean water is a valuable resource to both the local and global community. Nonetheless, a lack of water to meet daily needs is a reality today for one in three people around the world [40]. As populations grow and the effects of climate change are realized, the demand for fresh water will increase and put a strain on both ecosystems and communities. The same goes for the Ashesi and the Berekuso township. Therefore there is the need to conserve water.

- **Personal** – Learning about water conservation and one's individual environmental impact is a critical step in making positive personal behavioral changes that can benefit everyone. This is exactly what this competition seeks to achieve. By giving students the opportunity to actively engage in this competition, they would learn about water conservation and even come up with strategies to encourage others to do so too.

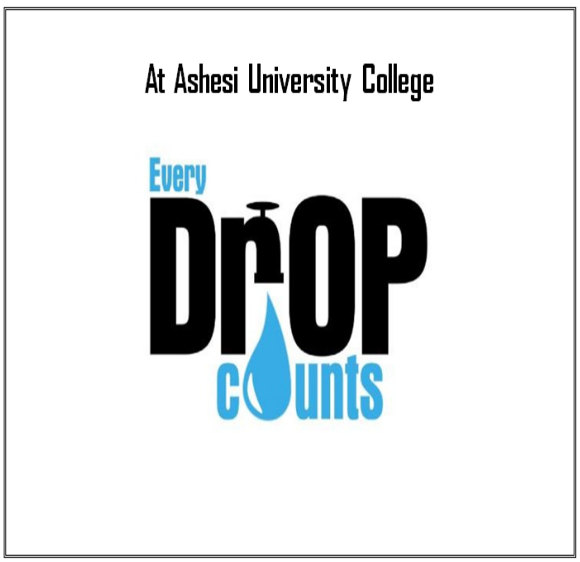
Reward/Incentive: Since this is a semester long competition, a great way to award the winning Dorm Block, would be for the school to fund a party to celebrate their victory. This would also be a good means of motivating the Dorm Block which didn't do well, to do better in the future. Better still; the reward system could be designed to represent a percentage of the savings that Ashesi makes when students conserve water. This implies that, the less water used by the students, the more money they will receive to fund their party.

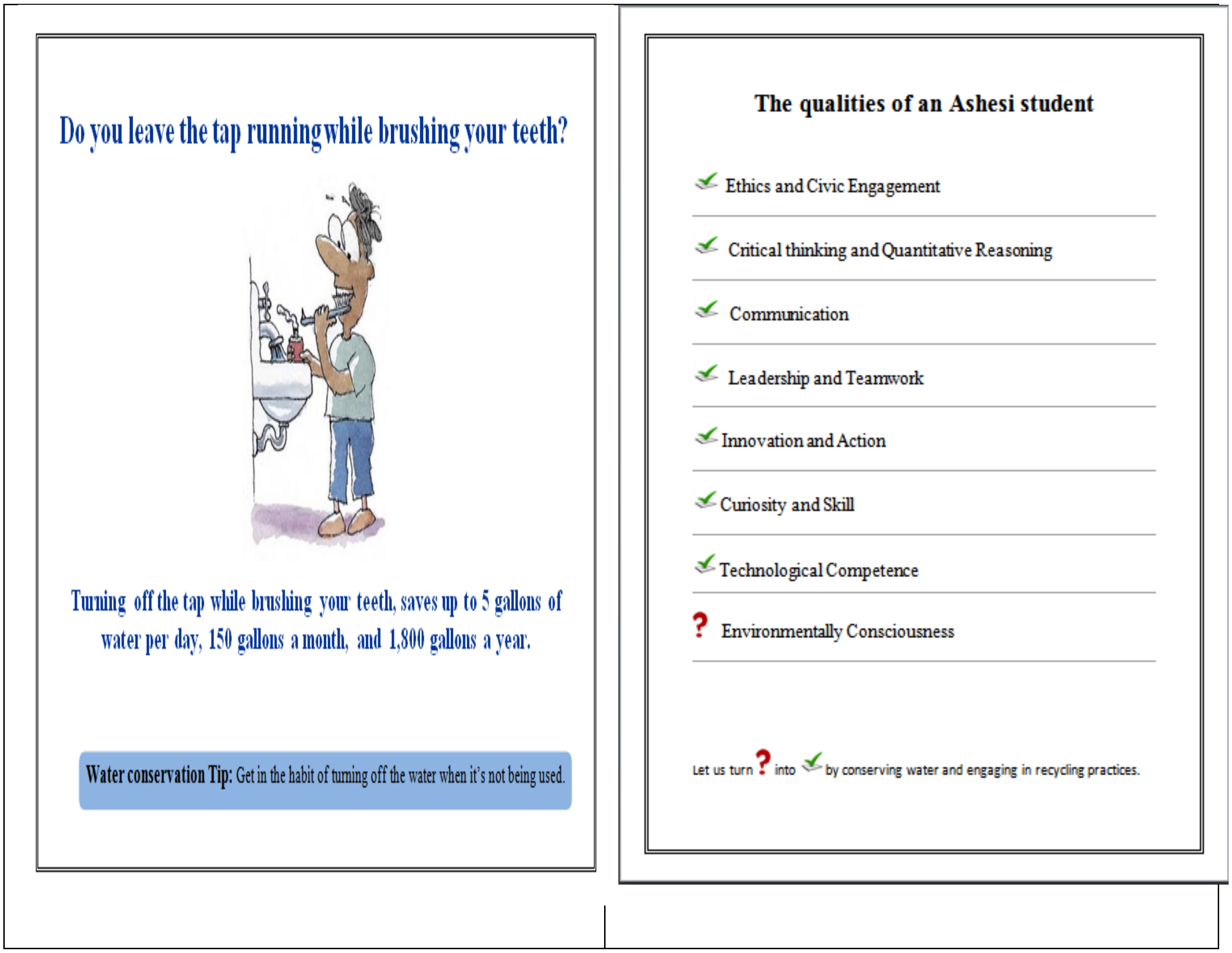
Apart from the above, debate and essay competitions could also be organized to get students to have meaningful conversations about water conservation.

Furthermore, there is a need to make the community members understand Ashesi's Water Treatment System. The results from the focus groups conducted revealed that, one reason why people were not comfortable with drinking the tap water on campus is that they were not really convinced about the system. They also mentioned that, perhaps, if they knew more about the system, they would be convinced enough to drink from the taps. To this effect, a poster/brochure has been designed to explain Ashesi's water treatment to the community in order to encourage people to drink tap water on-campus. It is highly recommended that, this brochure or a similar one, be given to new students during orientation.

Water Awareness Posters

The water posters were designed with a simple message. To give a fact about the water situation on campus or in the world and to give a conservation tip to serve as a reminder to people. Below are some sample posters for water awareness which are to be placed at vantage points (notice boards and close to taps) on Ashesi's campus.





Some other ways of reaching out to students are having water conservation discussions during townhall meetings and orientation. Also, by putting updates about the water conservation measures in the school bulletin, the Ashesi community as well as outsiders can get to know

Awareness Strategy Recommendation

Making readily available resources to induce student behaviour and encourage them to be environmentally conscious will be a great starter in a bid to achieve the solutions proposed in this strategy. To this end, it is strongly advised that, Ashesi engages in

1. Distribution of Orientation Kit: It is highly recommended that Ashesi (perhaps, Dean of Student and community affairs) puts together an orientation kit, that includes the under listed to make it easier for students to practice being environmentally conscious:

   - An Ashesi branded reusable tote bag
   - An Ashesi branded reusable water bottle
   - A plastic bowl for buying food

- An environmental brochure detailing the environmental practices and policies at Ashesi
- A brochure of the water treatment system

2. Publically advertise campus conservation efforts taken by the administration, so students recognize water conservation is a priority across campus—not just a priority for student behavior.

3. Integrate water education into any awareness campaign. Students who understand the water system, costs, and benefits of conservation habits will be more likely to take water conservation seriously.

7. EVALUATION

The iSTEP researchers conducted three surveys, several formal and informal evaluations of the technology, and received feedback from campus community members about the perceived successes of the project and opportunities for its continuation. With the strong support of faculty, staff and the institutions, administration, the issues addressed by the project may continually be investigated and approaches to confront those issues should be developed and sustained.

An extensive logic model for outputs (deliverables) of waste project was developed to facilitate evaluation of short-term, medium-term and long-term outcomes of the project over the next three years. This model identifies metrics to assess the effectiveness of the outputs of iSTEP 2012 in terms of achieving a specific set of outcomes over time. Those responsible for carrying the project forward after the iSTEP summer program will be responsible for monitoring development in the outcomes, comparing the changes in the metrics gathered at specific intervals respective to each outcome period.

7.1 Current Data Collection System: Water

Prior to the arrival of iSTEP interns, operations personnel collected no historical data on water supply or consumption levels on the campus. As a strategy for collecting data to aid in assessment of the issue, interns began collecting daily readings from each analog meter placed at three campus locations: one at the administrative block, two at the hostel block.

This system requires that individuals tour the locations of the meters at least one time a day, systematically recording the numbers indicated on the meter faces. Once this information is collected, it may then be transferred into a spreadsheet for further analysis. Time and labor costs are the main expenses associated with the current data gathering method. Additionally, personnel must be knowledgeable of programs such as Excel, which can be populated with the gathered data and used in analysis and trend plotting. This system must be consistently monitored for consistency of data collection, management and human error.

The diagram below outlines the manual water data collection system implemented by iSTEP interns to gather data about water use on campus. Key disadvantages to this system include that it:

- Relies on human intervention
- Is prone to inaccuracies, human error
- Is decentralized
- Information not available for public use

- Features data in a non-graphical format
- Not sustainable if not a part of operations personnel's regular duties
- No historical data log

Figure 29. Manual water data collection system

7.2 Current Data Collection System: Waste

After the completion of a waste audit, the interns were able to use the data to extrapolate waste production levels according to proportion of certain waste categories (organic, plastic, paper, electronic, etc.). These projections allowed the team to estimate how long it would take for a significant mass of recyclable waste to be accumulated and ready for transport or collection by recyclers.

A two-week pilot waste segregation program for plastic bottles was implemented to test potential modes of effective awareness generation activities. Well-labeled, specially designed bins (see Figure 25) were placed at high traffic locations around the campus to collect empty plastic bottles. Cleaning staff periodically emptied the bins and recorded the number of bottles collected.

Similar to the manual water monitoring system, currently, individuals must consistently record the levels of waste collected at each bin site. This information must then be organized and managed with the help of spreadsheet software. Similarly, this method requires consistent data collection, significant management oversight and is prone to human error.

The diagram below outlines the manual waste data collection system implemented by iSTEP interns to gather data about waste on campus. Key disadvantages to this system are identical to those of the water data collection system.

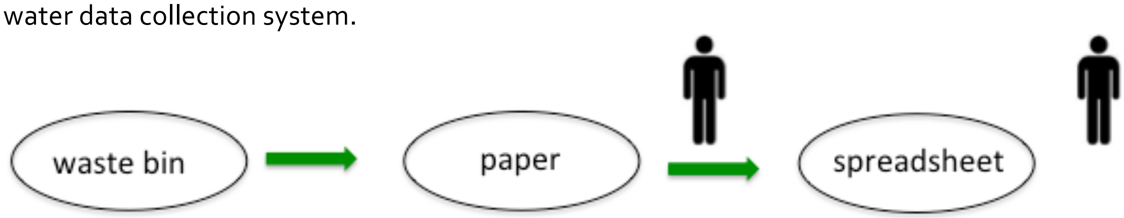


Figure 30. Manual waste bin data collection system

7.3 Technological Solution for Data Collection

A three component technological solution was developed to track the supply and usage of various resources and materials on campus. In the scope of iSTEP 2012's goals, the solution tracks water and waste levels.

The first component is an SMS program that allows users to manually input data into a text message on a mobile device and then transmit it to a centralized database where the information is stored and organized. The user must continue daily touring of the meters, but can now send the readings directly into the database via an SMS formatted to include the meter's identifying information (location and ID number). This SMS application can be applied to the collection of data about any measureable substance including waste, electricity, etc.

The second component of the system is a content management system (CMS), which serves as a repository for data that is collected at each meter or resource monitoring location. The CMS has an interface that allows users to manage data collection locations, add and manage sensors, manage system users and view all readings. The system will also check for anomalies in the data, which may be caused by human error.

The third component of the system is a publicly accessible web-based user interface which provides access to aggregate data in the form of bar and line graphs which represent trends in water usage or waste accumulation. Stakeholders and anyone with access to the Internet will be able to use this program. Additionally, the interface will provide users with the ability to view updated water quality reports, waste and water system maps, and related information.

The diagram below outlines the SMS input data collection system that incorporates the technology solution developed by the iSTEP team. Its advantages include:

- Less reliant on human intervention
- Features a graphical display of data
- Is centralized: aggregate information can be managed at one location
- Provides historical log of data
- Information available for public use

Its disadvantages are:

- Not completely immune to inaccuracies and human error
- Effectiveness relies on technology adoption into operations personnel's regular duties
- Easily impacted by lack of connectivity (internet, wireless signal)
- Costs associated with: sending SMS messages from various wireless carriers (3-4 pesawas), electricity used by server and computer systems
- Requires skilled individual to maintain system

Figure 31. SMS input data collection system

In the future development of the solution, automatic digital sensors will likely be employed to collect readings and transmit them wirelessly into the database. This digital method will include limited human involvement, lessen human error and cut labor costs associated with the methods currently used to gather the information.

The diagram below outlines the digital sensor input data collection system that incorporates the technology solution developed by the iSTEP team. Its advantages include:

- Not reliant on human intervention

- Immune to human error
- Features a graphical display of data
- Is centralized: aggregate information can be managed at one location
- Provides historical log of data
- Information available for public use

Its disadvantages are:

- Effectiveness relies on technology adoption by operations personnel's regular duties
- Easily impacted by lack of connectivity (internet, wireless signal)
- Costs associated with: attainment of sensors, installation, housing infrastructure, electricity used by server and computer systems
- Requires skilled individual to maintain system

Figure 32. Digital sensor input data collection system

The technical solution developed creates advantages to be experienced by the operations personnel and the entire Ashesi community. With the implementing of the fully automated system that uses a wireless sensor network, operations will not have to deploy personnel to collect data. Additionally, because there is no need for human interaction with the data before it is organized, there will be fewer instances of inconsistencies due to human error. Additionally, a range of Ashesi stakeholders and other members of the public will have access to a catalog of historical data about the institution's resource management.

7.4 Improved Water Monitoring and Management at Ashesi

Ashesi expressed that the institution wishes to measure and monitor water usage and waste generation on campus on a regular basis. Measurement of these resources and substances will facilitate better management and policy creation through:

- Increased information to decide how to expend water resources from borehole or rainwater holding tanks
- Increased ability to identify leaks

A fully digital system that implements three wireless pulse meter sensors will enable operations personnel to better manage the water resources on campus. The system can be expanded as the water infrastructure grows with campus additions. Data will drive decisions regarding how much rainwater to keep stored and how much to release for use. Data can provide information about water consumption levels to aid in decisions about costs associated with running the borehole pump.

If operations personnel have data that informs them that they should employ water resources from stored water tanks, costs of providing water to campus should decrease significantly in comparison to the current system.

The current scenario at Ashesi, related to water management, is that operations personnel use the borehole as a primary source of water. If the borehole fails, a water tanker is hired to recharge the water system. The cost associated with the tanker is exceptional. Rainwater collection holding tanks are used as a backup when the pump at the borehole malfunctions.

Scenario one assumes that the borehole and rainwater sources will be used equally. The automated system of sensors and meters would feed data into the database and allow operations personnel to determine when to shut off one source and use the other.

Scenario two assumes that the rainwater holding tanks have capacity enough for use by the campus population on a daily basis. The borehole will only be sourced as a secondary alternative at depletion of the rainwater reserves. This should be assumed as the best option for the campus community and the overall Berekuso village. It is more expensive than a 50-50 use of each water source, but the value is found in that it conserves the water table's resources.

The third scenario considers the borehole pump being used as the sole source of water, with rainwater held only as reserves for emergencies. The daily cost of the borehole is five times larger than daily rainwater cost.

7.5 Improved Waste Monitoring at Ashesi

Information about waste levels produced by the campus will advance the institution's efforts toward environmental sustainability. Data about waste levels will serve several purposes including:

- Inform administration's policy decisions
- Indicate to campus community which types of waste should be reduced
- Provide information useful in negotiating contracts with waste collection services
- Notify operations personnel when critical mass has been reached and recyclable materials can be given to appropriate companies

7.6 Solution Evaluation

The researchers conducted evaluations on three components of the solutions developed to address the issues within the scope of the iSTEP project. The evaluations included surveys and observations. The three evaluations included assessment of:

1. Pilot awareness program
2. Technology solution
    a. Development feedback
    b. End user testing

7.6.1 Evaluation of Pilot Awareness Program

The pilot awareness program consisted of two components that targeted the campus community's behaviors regarding: disposal of plastic bottles and disposal of tissue paper. The team conducted a status check of the bins and posters used for the pilot programs, as well as pre- and post-intervention surveys to measure the effectiveness of the pilot awareness campaign. The aim of the surveys was to understand the impact of the pilot awareness campaigns and the modes of communication for such activities. The researchers chose to gain an understanding of the effectiveness of the pilot program using these methods so that future initiatives to target behaviors around waste and water issues will utilize tactics that are most feasible within the Ashesi's unique environment.

Condition of Pilot Materials

The researchers collected data through observations of the conditions of awareness materials and bins after the 14-day pilot awareness program. Posters that had been displayed during the pilot were checked to see if they were still affixed to their original places and if the adhesives used were adequate. Bins were checked to see if labeling was still present and in legible form, whether lids were still affixed, if they had been relocated, and if any materials other than plastic bottles were found within the receptacle. Researchers also checked surrounding waste bins for plastic bottles. These observations revealed useful considerations for implementing the awareness program over the longer term.

Status of mesh bins placed for collecting plastic bottles (all 10 bins were checked):

- All the bins were upright, fixed properly and located in the same location as they were placed (despite wind and rain during the week).
- The labels placed on the bins were intact and clear.
- Most of the trash placed in the mesh bins were plastic bottles. However in two bins, instances of tissue paper and books were observed in the mesh bins.
- Instances of plastic bottles being placed in bins other than mesh bins were observed in three locations. A closer observation revealed that plastic bottles are placed in other bins where mesh bins were not in close proximity.

Status of the posters displayed in connection to tissue paper use (sample of 18 out of 118 total posters were checked):

- All the posters evaluated were still affixed (despite wind, humidity in the wash rooms).
- All the posters fixed with push pins were in good condition.
- All the posters fixed with cello tape were curled (due to humidity and also peeling off of the cello tape).
- An instance of a poster falling off the door was also observed in one location.

Pre-intervention Survey

Prior to the pilot implementation, a paper survey was deployed to gain baseline understanding of various practices that would be targeted by the pilot waste program. The pre-intervention survey asked respondents questions regarding current recycling habits, the presence of recycling awareness materials, how tissue paper is disposed, individuals' understanding of tissue paper disposal and to how one would prefer to receive information about environmental sustainability initiatives. The questions utilized in this survey are included in Appendix III. Question topics covered by the survey included:

- Recycling of plastic bottles
- Flushing tissue paper
- Flushing items other than tissue paper
- Preferred methods of communication on campus
- Social media usage

Post-intervention Survey

Following one week of running the pilot program, a second paper survey was distributed to those present on the campus. The survey asked the same questions that were present on the pre-intervention survey and additional questions that would help the researchers understand the effectiveness and penetration of components of the pilot program. The post-intervention survey sought to gain an understanding of the visibility of pilot waste recycling awareness communication efforts, use of newly installed receptacles for plastic bottles and whether behaviors or perceptions had been influence by the pilot awareness campaign. The questions utilized in this survey are included in Appendix III. The additional question topics included:

- Visibility of posters about plastic bottle recycling
- Visibility of posters regarding consumption levels and flushing of tissue paper
- Accessibility of plastic bottle collection bins
- Receipt and perception of pilot update email messages

Response rates for the respective surveys are included below (Table 8).

Survey	Total responses	Students response (Freshmen)	Faculty and staff response
Pre-intervention	31	18	13
Post-intervention	32	23	9

Table 8. Pre and post intervention survey response rate

As with other aspects of these projects during iSTEP 2012, the members of the freshmen class were the only Ashesi students present on campus during the pilot program. Therefore, they represent 100% of the student responses. An analysis of the responses is presented in the following sections.

Analyzing the Impact of the Awareness Campaign

The pilot awareness campaign was successful in improving the knowledge of recycling of plastic bottles and flushing tissue paper as can be seen from the survey responses in Table 9.

Topic/Response rate	Students		Faculty and staff	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Are plastic bottles recyclable?	91%	96%	88%	100%
Is tissue paper flushable?	100%	96%*	88%	100%

Table 9. Survey results - Knowledge of recycling

*One respondent indicated "no" to this question but indicated in other parts of the survey that they had seen the posters in the washrooms. Given their response, perhaps the question was not worded clearly.

The posters used for the awareness campaign (Figure 26, Figure 28) have achieved heavy penetration in the target community as can be seen from the survey responses in Table 10. The posters achieved 96% visibility among students and 88% visibility among faculty and staff indicating that most of the sample of stakeholders noticed the posters.

Topic/Response rate	Students	Faculty and staff

	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Have you seen posters about plastic bottles on campus?	9%	96%	13%	88%
Have you seen posters about flushing tissue paper on campus?	45%	100%	75%	88%

Table 10. Survey results – Penetration and visibility of posters

The posters used for the awareness campaign (Figure 26, Figure 28) were very noticeable and easy to understand as can be seen from the survey responses in Table 11. It is important to note that the response rate for faculty and staff is lower compared to students.

Topic/Response rate	Students	Faculty and staff
How noticeable are posters used for plastic bottles (response rate for very noticeable)?	70%	50%
How easy is it to understand the posters for plastic bottles (response rate for very easy)?	91%	63%
How easy is it to understand the posters for tissue paper (response rate for very easy)?	91%	75%

Table 11. Survey results – Ease of location and understanding of posters

Analyzing the Impact of Communication Regarding the Awareness Campaign

An introductory e-mail detailing the awareness campaign was sent to all stakeholders of the campus followed by weekly update mails for two consecutive weeks. Analysis of the communication is presented below:

- Posters served as a major form of communication regarding the pilot awareness program (63% of the respondents knew about the pilot awareness through posters, 34% through e-mail and 25% through word of mouth)
- Considerable number of stakeholders received the update emails and found the emails to be informative and motivating (63% of the respondents received e-mails and 66% of those received expressed that the e-mails were motivating and 9% of those received expressed that the e-mails were not motivating)
- A major portion of the stakeholders want to receive further communication through Ashesi e-mail (41%), Ashesi website (25%) and through social media like Facebook (19%)

The results from the evaluation of the awareness program lead the team to believe that Ashesi community members are fully engaged in the life of the campus, aware of changes and new initiatives, and are receptive to materials that intend to alter behaviors towards environmental sustainability. The researchers note that a diverse communication strategy involving email, posters and social networking platforms can reach the greatest numbers.

Evaluation for the Awareness Plan

A summary of the activities proposed, key personnel involved, timeline for the proposed awareness plan with the evaluation metrics are presented below:

Activity	Key personnel	Evaluation metric
Using paper bags/ recyclable paper and plastic bags	Dean of Student and Community Affairs in coordination with the catering contractor and the convenience stores	
Implementing 'ask for a plastic bag' policy		Implementation of the policy during fall semester
Awareness campaign about water cleaning system through video campaign and posters	Dean of Student and Community Affairs	Dissemination of the video at the orientation fall semester
Awareness campaign about water testing procedure through dissemination of monthly reports	Operations management	Dissemination of water testing report before the first week of the following month
Installation of water fountains and coolers	Operations management and development committee	Installation of at least one water cooler (as a prototyping) during fall semester
Implementing alternate strategies in lieu of use of Styrofoam	Dean of Student and Community Affairs in coordination with the catering contractor	
Imposing a ban on use of Styrofoam	Dean of Student and Community Affairs in coordination with the catering contractor	Implementation of the policy by end of fall semester
Considering options for reduction of paper use on campus	Dean of Academic Affairs	
Considering options for double sided printing	Dean of Student and Community Affairs in coordination with the IT department	
Developing policies for usage of consumables like cartridges	IT department	
Exploring options for recycling/reusing the consumables/cartridges	IT department	
Source segregation for plastic bottles	Dean of Student and Community Affairs in coordination with the operations group	Tracking the volume of plastic bottles collected and recycled on a weekly basis
Encouraging flushing tissue papers through posters	Dean of Student and Community Affairs in coordination with the operations group	
Exploring options for reusing the cardboard boxes	Dean of Student and Community Affairs in coordination with the catering contractor and the convenience stores	

7.6.2 Technology Development Feedback

The technology developed during the internship sought to meet the needs and expectations of the partners, potential end users, and other stakeholders. Therefore, the researchers conducted several iterative phases of development of the technology solution. Data was collected from an initial technology evaluation in the early stages of development. One formal evaluation and several informal feedback sessions were conducted to guide the tech team throughout the iterative technology development process. Criteria from PREval Framework were used to assess the technology. The PREval (Pilot Research Evaluation) Framework was developed to assist researchers in assessing pilot ICTD field research projects [8]. This document was created by TechBridgeWorld researchers to address the need for such a tool in the field. PREval is based on existing tools for evaluation and on TechBridgeWorld's experiences conducting field research in ICTD. It offers insight into planning and executing a comprehensive and structured project assessment, comprising of a process evaluation, technology assessment and outcome evaluation.

The PREval criteria include:

- Functionality – How well does the technology work and accomplish the intended tasks?
- Usability – Whether a range of users may easily use and understand the function of the technology, particularly those that are not experienced with said technology.
- Reliability – Whether the technology produces error and its ability to successfully function in the capacity that it was intended.
- Suitability – Is the technology appropriate given the unique conditions of the environment where the solution will be implemented?

Key findings include considerations made in regard to the aforementioned criteria. This internal evaluation was conducted among the researchers themselves. These findings are summarized below.

7.6.3 SMS Software Development Feedback

Functionality

- Database which receives inputs needs multiple connectivity options: internet and local server hosting
- Need for data anomaly detection
- System should not allow input from non-authorized users

Usability

- Formatting must be easy for users on QWERTY, alpha-numeric, and touchscreen input interfaces
- Need for simple, yet informative instructional resource that guides novice user through the software
- Lack of signal range of some mobile phone carriers will cause the system to be unusable
- Program requires common knowledge associated with operating a mobile phone

7.6.4 Content Management System Development Feedback

Functionality

- Software must be hosted on a computer system that is agile
- Need for data anomaly detection
- Requires features which minimize user's potential for input errors

Usability

- A uniform and organized method of displaying data inputs must be implemented
- Requires a clear and legible interface which uses color and non-jargon terminology to clearly express functionality
- Need for simple, yet informative instructional resource
- Data inputs should be sorted logically: descending chronological order, by user, by sensor location (sort function)

Reliability

- Software must be hosted on institution's proprietary serves in order to be immune to internet connectivity issues
- Additionally, the sever must be free of viruses and interfering programs

7.6.5 Data Visualization User Interface User Development Feedback

Functionality

- Interface should employ captivating yet informative graphics
- Program must meet the data needs of a wide range of users including students, administrators, and public
- Controls and features should be oriented ergonomically from top to bottom, left to right

Usability

- The user interface must use color and graphics to create meaningful illustrations of data
- The flow of features on the screen must be easy to use and navigate
- Coordinate axes, units and other labels must be properly indicated in clear terms which are understandable to a range of users
- A simple query function must be implemented that allows users to quickly find data
- Need for simple, yet informative instructional resource

Reliability

- Software must be hosted on institution's proprietary serves in order to be immune to internet connectivity issues yet remain accessible to public
- The sever must be free of viruses and interfering programs.

Suitability

- The software must be intuitive enough for the comprehension of novice users
- Basic instructions must be in appropriate language that is easily understandable and clear

This feedback was summarized and shared with members of the technology development team. They incorporated the feedback if time allowed, or planned to include the findings as recommendations for further development of the technology.

7.6.6 End User Testing

The researchers conducted a final testing with four end users. These users completed a trial of one or more of the components of the Ashesi Resource Tracker. The same users were asked to participate because they will potentially use the technology on a daily basis to collect information about resources measures, given their roles on the campus. The researchers developed a framework to be used in initial technology evaluations to incorporate assessment of user experience and impact of external forces on the technology's ability to function and serve the intended purpose. This framework includes elements from the PREval Framework (functionality, usability, reliability, and suitability), as well as cost:

Users were given a one-hour training session on the day prior to end user testing. Users consisted of three operations personnel and one member of the faculty. Testing sessions lasted from thirty minutes to one hour. Instructions on how to use the three components to the technological solution were given verbally. The required formatting of the SMS message was indicated on a whiteboard. The training followed a format that included familiarizing users with the components, mirroring the order that they would be used in real scenarios: first, SMS software; then, CMS software; finally, visualization interface.

SMS Software Testing

Users were taken to parts of campus where they read the meters and input the readings as an SMS, then transmitted it via their personally owned mobile phones to the content management system.

They continued collecting meter readings from each of three meters, adjusting their SMS submissions based on confirmation text messages sent by the SMS software. If the user made an input error, the system's reply message prompted re-entry. If the user did not make an error, he/she moved on to the next meter after receiving notification that the information was received by the system. The majority of users made no errors inputting the meter readings with the SMS application. One user had several input errors resulting from incorrect formatting. Confirmation and error messages were received when appropriate. All users reported that they fully understood what the messages meant.

CMS Software Testing

Some users then moved on to test the content management system. The researchers prompted users to conduct key functions of the software: adding a location, adding a sensor and adding a reading.

The content management system requires some working knowledge of using a computer and interacts with user interfaces. Most users were able to navigate the interface, but did mention that an on-screen instruction resource would be useful. They reported that the interface was not entirely intuitive. There was a consensus that better organization of the data in the list of readings would be helpful to users as they survey data entries.

Visualization Interface Testing

The users then tested the visualization user interface to view graphical representations of the data. They were prompted to engage the system through several queries of data. Additionally, users were instructed to test the informational links provided on the interface.

Users were able to query data without much instruction apart from the training they had received the previous day. The query is not entirely intuitive. It requires users be knowledgeable of the resource monitoring infrastructure, and may not be entirely suitable to all users. The graphs were well understood, but some details were not clear to users. The uncertain details included: two meters being represented by one trend line; the aggregate amount of resources tracked within a given time period.

Conclusions from User Testing

Overall, the technology solution was well received by the four users. Field testing was particularly successful with the SMS application. Users were less able to navigate the content management system without clues and coaching. Not many user errors were observed, but there was uncertainty about the system's response to user inputs. The visualization user interface was easy for users to use, but requires some tweaks before it can be effectively used by a range of users.

7.7 Post-iSTEP Evaluation: Measuring Outcomes

7.7.1 Waste monitoring project outcome logic model

Outputs

A. Ashesi Resource Tracker
B. Technological solution: load sensor, ultrasound sensor
C. Pilot segregation scheme
D. Awareness campaign
E. Policy recommendations

Short-term Outcomes (0-1 Year)

1. Better understanding of waste composition
2. Technological adoption and acceptance by school
3. Increased capacity for data collection
4. Less waste to landfill

Output	Outcome	Metric	Method	Current
A, B	1, 2, 3	Number of data points collected with load sensor over period	Count	0
A, B, C	1, 2, 3	Number or reports released that include data provided by technological solution	Count	0
A, B, C	2, 3	Decreased level of difficulty required to gather data	Survey	No data
A, B,	2, 3	Decreased time required to gather data	Time	No data
A, B, C, D	1, 4	Percentage decrease in amount of waste sent to landfill	Waste audit, data validation	100%

Table 12. Waste monitoring short-term outcomes and metrics

Medium-term Outcomes (1-3 Years)

1. Reduction of waste production
2. Increase reuse and recycling

3. Decrease in waste disposal expenditure
4. Introduction of waste policies

Output	Outcome	Metric	Method	Current
B, C, E	1, 2, 3, 4	Percentage increase in amount of waste reused/recycled	Data audit	0%
B, C, D, E	1, 2, 4	Percentage increase in number of people that report recycling and reusing	Survey	Yes: 13.7%, No: 80.39%
A, C, D, E, F	2, 4	Percentage increase in number of people that report recycling as "important"	Survey	Very important: 58.82%, Somewhat important: 53.92%
A, B, C, D, E	1, 2, 3, 4	Percentage decrease in waste collection expenses	Financial validation	GHC 900 per month
B, C, D, E	1, 2, 3, 4	Increased cost-savings thru alternative waste management (recycling, composting)	Financial validation	0
E	4	Number of waste specific policies implemented by administration	Evaluation	0
E	2	Increase in number of students engaged as members of environmentally focused organizations/clubs	Survey	No data

Table 13. Waste monitoring project medium term outcomes and metric

Long-term Outcomes (>3 Years)

1. Implementation of composting plan
2. Ashesi-Berekuso community partnership

Output	Outcome	Metric	Method	Current
C	1	Percentage decrease in fertilizer expense	Financial validation	No data
C, D, F	1	Percentage increase in use of organic fertilizer from composting unit	Data validation	No data
B, C	1, 2	Percentage decrease in amount of organic waste to landfill	Waste audit, data validation	100%
C, D	2	Number of environmental projects undertaken with Berekuso community	Count	0

Table 14. Waste monitoring project long-term outcomes and metrics

7.7.2 Water Monitoring and Management Project Outcome Logic Model

An extensive logic model for outputs (deliverables) of waste project will facilitate evaluation of short-term, medium-term and long-term outcomes of the project over the next three years. This model identifies metrics to assess the effectiveness of the outputs of iSTEP 2012 in terms of achieving a specific set of outcomes over time.

The accompanying tables correlate the metrics to the outcomes that they indicate and their relation to the outputs delivered by the iSTEP projects, specify how the information should be gathered and what the current data point is.

Outputs

A. Sonar depth meter to measure rainwater tank levels
B. Implementation of digital volume sensors for that wirelessly transmit data to database
C. Ashesi Resource Tracker
D. Database content management system
E. User interface that facilitates visualization of data to public
F. Awareness campaign
G. Policy recommendations

Short-term Outcomes (0-1 Year)

1. Technology adoption and acceptance
2. Better understanding of water resources distributed and supplied
3. New and better capacity for information gathering: in level of difficulty to obtain and manage data
4. Introduction to water conservation themes
5. Awareness of Ashesi water situation

Output	Outcome	Metric	Method	Current
A, B, C, D	1, 2, 3	Number of data points collected using Resource Tracker	Count	0
A, B, C, D	1, 2, 3	Time spent per day/weekly by operations personnel using technology	Time	0
C, D	1, 2, 3	Number of data points transferred to CMS per period via SMS	Count	0
C, D	1, 2, 3	Number of data points manually input into CMU per period	Count	0
A, B	3	Decrease in time spent collecting one round of water meter data	Time	10+ minutes
E, F	4, 5	Increase in percentage of community members that report water conservation as being	Survey	Very important: 72.5%,

		"important"		Somewhat important: 26.47%
E, F	5	Instances of environment themes on website, at town-hall meetings and orientations	Count	0
E, F	5	Number of visitors to Ashesi Resource Tracker webpage per period	Count	0
E	5	Number of downloads of Ashesi Resource Tracker datasets per period	Count	0

Table 15. Water monitoring and management project short-term outcomes and metrics

Medium-term outcomes (1-3 Years)

1. Conservation principles adopted by community
2. Behaviors altered towards mindfulness of water resources and its consumption
3. Water related policies
4. Community members comfortable drinking tap water

Output	Outcome	Metric	Method	Current
E, F	1, 2	Percentage increase in community members that report water issues as being "important"	Survey	Very important: 72.5%, Somewhat important: 26.47%
G	3	Number of water related policies implemented by administration	Count	0
E, F, G	1, 2	Percentage decrease in observed/reported wasteful water practices	Survey	54.9%
F, G	4	Percentage increase in community members that drink campus tap water	Survey	56.86%

Table 16. Water monitoring and management project medium-term outcomes and metrics

Long-term Outcomes (>3 Years)

1. Environmental consciousness inculcated as tenant of Ashesi culture
2. Monetary and resource savings realized

Output	Outcome	Metric	Method	Current
E	1	Number of student theses with environmental themes	Count	0
A, B, C, D, G	2	Percentage decrease in water expenditure	Financial validation	No data

Table 17. Water monitoring and management project long-term outcomes and metrics

7.8 Educational outcomes

The technology deliverables of the iSTEP project present educational opportunities for students and researchers. There are two main parts that may be used in the classroom or in experiential learning scenarios. These include:

- Data produced and stored by the system
- Development of technology, expansion of system

Through the publicly accessible visualization user interface, individuals will have access to time series data about resource consumption of water and production of waste on the campus. These data sets will be applicable to statistics courses and other quantitative-based analytical endeavors such as data mining.

The end of the iSTEP internship summer does not cue the end of the development of the Ashesi Resource Tracker. Upon the implementation of a more automated system of sensors, the system will encounter a continual expansion and evolution. Ashesi's curriculum—which offers course in robotics, computer science and business—may create opportunities for students to assist in the development of the system. Students may work on the system's development through theses, business plans, and other projects.

Additional educational outcomes may be realized through the inclusion of environmentally conscious themes during new student orientation, information sessions, and field visits.

7.9 Evaluation Conclusion

The evaluation of the iSTEP deliverables occurred during the end of the internship and should be continued alongside the development of the technology and implementation of awareness programs and policy recommendations. Given that the iSTEP internship took place during Ashesi's long vacation session, information gained from needs assessment and evaluations may not properly reflect the realities of the regular school year. Recommendations on obtaining more accurate baseline data for evaluation and monitoring of outcomes and ensuring sustainability may occur through the following activities:

- Roundtable discussion with Ashesi stakeholders regarding implementation of suggested awareness strategies to develop responsibilities and jurisdiction over certain aspects of solution implementation
- Waste audit conducted during regular school year (when campus is at regular operation)
- Survey about the perceptions and behaviors regarding waste and water prior to implementation of technology solution and awareness programming
- Gathering of indicators (see logic model) prior to implementation solution and at key intervals after solution implementation
- Survey at key intervals (see logic model) after the implementation of technology solution and awareness programming

8. RECOMMENDATIONS AND LONG TERM PLANNING

8.1 Water Long Term Solutions

In order to address Ashesi's long-term water priorities the university should consider four particular long-term components: Management and technical requirements to continue iSTEP's work, infrastructure options to reduce water use, an awareness campaign and rainwater management.

8.1.1 Recommended Management and Technical Requirements

During the 10-week internship the team developed (1) an SMS and mobile platform to input data from four analog sensors, (2) a content management system to store the data, and (3) a web-enabled user interface to make data accessible. The team also began the installation process for three digital sensors. The team also devised a working management strategy for best-use of rainwater based on the real-time data now available. In order for these systems to meet their intended use, which is to help Ashesi monitor water and collect time-series data, and better manage rainwater use, we propose the following recommendations.

Data Management

- We recommend creating a new sensor in the CMS for the borehole readings. Currently operations staff collects data from the water meter at the borehole but that data is not stored in the SMS or CMS system. Per the instruction manual, we recommend creating a new sensor location and begin imputing the data on a daily basis directly into the CMS.
- We recommend that data should be collected at minimum on a daily basis; operations management will need a reliable, low-oversight cost strategy to ensure operations staff or students collect metering data via the SMS option. Given the iSTEP 2012 project scope was to develop a prototype digital sensor option, and not a full-scale digital solution, a manual management strategy is required for data collection.
- We recommend that the data input into the content management system should be reviewed frequently to ensure the accuracy of the data. There are several potential locations for lost or inaccurate data ranging from human error to battery and other technical failure. Currently the only method for ensuring accurate and frequent data collection is through human oversight.
- We recommend that Ashesi devise a strategy for who will be charge of both the CMS and the web interface. This includes regular maintenance, debugging, and other tasks that the university identifies.

Rainwater Management

- In order to better manage rainwater, we recommend that Ashesi utilize a digital water volume meter to increase the use of rainwater. We suggest Ashesi should switch from using borehole water to rainwater when the rainwater tanks reach 50%during the rainy season. In order to do this we recommend that there be a clear strategy for who is responsible to monitor the volume levels on the web-enabled user interface and then who is responsible for physically turning on the rainwater pump. Once clear roles are developed, using rainwater will likely save operations staff time because they will not have to go to the borehole at the bottom of the hill to turn the pump on and off.
- To save on costs, we recommend that Ashesi utilize the rainwater generator. Currently, rainwater serves two goals; storage in the event of borehole failure and for direct consumption. Based on interviews with various engineers the cost of running the generator for the rainwater tanks is roughly 20-30 percent of the cost of running the generator for the borehole, or $10-17 a day. The borehole currently uses diesel, while the rainwater generator relies on electricity, which is far less expensive. While a transformer has been purchased so the borehole can also run on electricity, the rainwater generator is on campus whereas the borehole generator must

pump water almost a quarter of a mile uphill. Even with the transformer, rainwater will still be a cheaper option.

In the event that the borehole pump fails, water is typically purchased. Purchasing water is very expensive, requiring 4-5 tankers per day at $180 per tanker, or $900 a day. Because purchasing water is so expensive, we recommend reserving some rainwater in the event the borehole is not operating properly. Figure 33 indicates the cost differences between sources.

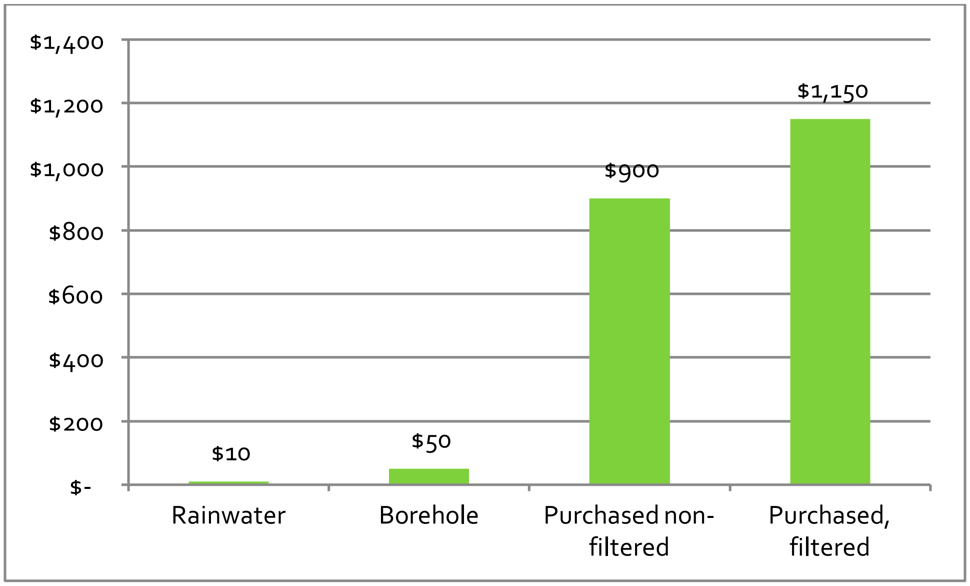


Figure 33. Cost of water at Ashesi University College

- Another consideration for Ashesi is: how much rainwater should be stored versus consumed? That depends on the likelihood of borehole failure. Since it is unclear how often the borehole will not be functioning, it is unclear what the right trade-off is, however, given the cost estimates and frequency of borehole failure during Ashesi's first year, we recommend storing 50 percent of rainwater during the rainy season.

8.2 Recommendations

8.2.1 Water Recommendations

The current status of development was reached by a small team in a ten week span. Some of the further actions recommended are to add a resource category table to the database and link all references to waste, water, rain water level, and any newly added resources through that.

The Anomaly Detection Module (ADM) and EDM can be improved upon over time as errors and oddities are found by users so that the patterns can eventually be identified automatically. In addition, Ashesi should consider implementing the following recommendations:

Data Collection

1. Install Waspmote sensors at all locations where there are currently analog sensors.
2. Develop explicit management plan for data collection.
3. Once sensors are installed, only a set portion (some percent of total capacity, such as 20 percent that is to be determined) of rainwater should be used for storage, while the rest is consumed.

Awareness

1. Publically advertise campus conservation efforts taken by the administration, so students recognize water conservation is a priority across campus—not just a priority for student behavior.
2. Integrate water education into any awareness campaign. Students who understand the water system, costs, and benefits of conservation habits will be more likely to take water conservation seriously.

Long-term Planning

1. Develop water conservation options that explicitly align with Ashesi's growth plan. Water conservation procurements should be written into construction contracts.
2. Explore options to better assess the capacity of the borehole's water table.

9. OVERALL INTERNSHIP EXPERIENCE

9.1 Student Reflections

Unlike many study or work abroad experiences offered by universities, TechBridgeWorld's iSTEP internship guides students on how to conduct technology field research in developing communities, an experience that is challenging yet rewarding. The following section features reflections from both the CMU and Ashesi interns who made up this year's iSTEP team.

9.1.1 CMU Reflections

Ronnell, Assessment Coordinator

The two-hour journey from Accra to Ashesi's campus requires one to take two tro-tros and a shared taxi through an assortment of paved, non-paved, dusty streets and roads from an urban to rural settling. Just as the bumpy road flanked by pineapple plots and cornfields reaches the perimeter of Berekuso village, one can see the Ashesi campus beaming on top of the hill. On a couple of nights, apart from the moon, Ashesi was the only source of light for kilometers as it is nearly immune from power outages on the national electricity grid because of its generators. As I witnessed this marvel, I was struck by the contrast: darkness and light.

Ashesi represents a light to many of its stakeholders, especially its students and employees. And because Ashesi is the bearer of many resources such as abundant electricity and water, it must employ a greater management responsibility. iSTEP was invited to be here partly to give perspective on how that responsibility might be managed using technology.

iSTEP has given me a hard look at the things that I am not strong at doing. I won't list them here, but I know what they are. From this experience, I have been able to engage in activities that I excel at, but I have also identified areas where I should focus my attention this coming academic year toward professional development and attainment of more skills that will prepare me for future work experiences. The structure of this internship gave me the opportunities to learn from teammates, TechBridgeWorld staff, and its network of research professionals.

Communication that accurately expresses one's need, uncertainties and intentions, is the most valuable asset to a team. This was a recurring theme throughout my iSTEP experience. It is rather simple, but very complicated. I strive to become a better communicator even in the face of setbacks, egos, Internet loss and personal health issues. Field work requires heightened communication even when the host country's official language is English.

In all my travels and time living abroad, I have really never felt so at home in a foreign country as I have in Ghana. I attended undergraduate studies in the southern United States, so I know what hospitality and close-knit communities feel like. Ghana has reminded me that people are capable of showing a high regard for strangers, embracing outsiders and showing sincere concern for the well-being of visitors to their communities. I am pleased that my second, but longest stay in Africa yet, was spent in this nation.

Corinne, Software Developer

My time in Ghana was as inspiring and intriguing as I expected it to be. I loved experiencing the culture and language, and noting the differences, as well as the fundamental similarities, across two very different continents. I had expected this internship would hold a lot of lessons for me regarding patience; I mentally prepared myself for the delays and frustrations that living and working abroad would hold. Those issues certainly occurred, including the unfortunate "frying" of my laptop's motherboard.

But rather than learning to value more patience and reserve, I recognized the importance of being pro-active and persistent. The search for information and quotes on sensors around the world couldn't be finished by template emails and web searches; we had to call, Skype, and call again to proceed. Many similar scenarios proved that an initial effort that isn't quite productive enough calls for new approach by another route. This doggedness is exhausting to put forth and can even be exhausting to co-workers who are jostled by it, but it's what was needed for the projects to proceed as far as they have. I was impressed by my team members who started with this attitude and challenged me to follow it, and I'm thankful to have learned from them.

Sandeep, Project Manager, Waste Project

The internship experience helped me to develop an understanding of working culture of students and professionals in Ghana. Working together with a diverse team of graduate and undergraduate students from CMU and Ashesi helped me to gain a perspective of different topics under discussion. The regular team meetings and brainstorming sessions helped to keep the project on time and to constructively develop the ideas for the project.

Scott, Project Manager, Water Project

On this project I learned the importance of thinking clearly about timelines in technology development projects and to consider tasks that may take longer than anticipated. I learned to be a flexible manager, and because the management role required leadership by consensus, to take the time to incorporate the team's ideas within project decisions.

Julie, Dissemination Coordinator

I spent eight out of the ten weeks on this project working at the CMU campus in Pittsburgh. Having to coordinate large projects (for example, this technical report) with multiple people over various time zones has been challenging. Now take that scenario and add technical difficulties like little or no internet connectivity, misunderstanding and miscommunication and the fact that everyone I am coordinating with has many other tasks that must be completed at the same time. This type of environment could easily lend itself to inefficiencies and frustration. Through this experience, I learned effective ways to move beyond the inherent challenges of working on a globally distributed team.

Some strategies I used included, starting my work day by 8 AM EST / 12 PM GMT and sometimes much earlier, in order to overlap with GMT work hours as much as possible. I also needed to be prepared ahead of time so that I would have extra time to ask the rest of the team questions with enough time for them to answer them. Always staying cognizant of the time-zone difference helped to keep the multiple tasks I worked on efficient and strong.

For the two weeks I was not in Pittsburgh, I had the amazing opportunity to join my teammates at Ashesi. I joined them in weeks eight and nine, so by that point the team already had a good handle on navigating from Accra to Ashesi, and on being acclimated to the culture and location in general. This gave me a leg up, so that upon arrival, I already felt acclimated because my teammates could clue me in on any questions I had about the new location. It also made me capable of getting a lot of accomplished in my short two weeks there. Working with the team in person was infinitely easier than working with them via Skype and email, two methods that fail to convey human emotion and understanding like a face to face conversation might.

This experience has prepared me for what might be a future of freelance work, working with people on the West Coast, while staying on the East. With this experience, I learned how to navigate the workplace almost 80% electronically and independently. At this point, I feel prepared for anything.

9.1.2 Ashesi Reflections

Juliana, Community Awareness

Irrespective of the fact that I have worked in a multinational team before, this experience was a totally different one. Personally, the major drive in this internship was the team's goal to create something tangible that my school could work with and use regularly. Coming right out of school, it was a good way to put all I had learnt into perspective, and the frequent meetings helped me get daily status updates on how close we were to achieving our goal. These daily meetings helped me in making informed decisions with respect to community awareness. Since it was such a small group, I had the special experience of working closely with every member of the team. Overall, I believe this was a worthwhile experience; all I have learnt during iSTEP 2012 is bound to come in handy as I go into corporate Ghana.

Diana, Dissemination

Little did I know how intensive an ICTD project could be until I participated in iSTEP 2012. I developed interest in ICTD in the classroom and also at the ICTD2012 conference in Atlanta, U.S. Thus, I was excited to be part of iSTEP to gain exposure into the rudiments of ICTD research and implementation. iSTEP helped me understand the importance of conducting thorough needs assessment, of working with a local community and of effectively evaluating the solutions brainstormed. The knowledge and know-how I have gained from iSTEP will enable me contribute to my country Ghana's development as I will continue to pursue my personal ICTD projects including the Readworm community library project and the Ghanaian sign language computer tutor project.

Maame, Longer Term Strategy

Being a part of the iSTEP 2012 internship was a positive boost to my Computer Science minor background from school. With the limited opportunities in the world for a Computer Science minor student like me, I considered this opportunity a good fit. Being on this team enhanced my knowledge on many environmental issues that I had not considered very necessary on a daily basis. From this experience, I definitely have become a better environmentalist and would continue to champion this course in my own little ways. Everyone is seeking and causing change in various ways around the world;

however, I appreciate that I have been able to influence my environment for that change through this internship experience.

Sonia, Needs and Evaluation

Personally, I didn't see this iSTEP internship as a job but a learning opportunity. In some respect you can say it was a job because we had scheduled starting and closing times, we were paid, we have supervisors, etc. But I also learnt that about 60% of Ashesi students place a high importance on recycling; I learnt that operations wanted sector by sector information on water distribution and usage; I learnt what a waspmote was. Every passing moment has been a learning opportunity and while the project has exposed me to best practices for managing water/waste, it has also allowed me to experience both the upsides and challenges that come along with working in an intercultural-interdisciplinary team. I have grown personally to be more methodical, thorough and open minded in my approach to work. Small opportunities do present themselves and serve as stepping stones for bigger things in life.

Selase, Data Gathering

From this internship experience, I really enjoyed developing the CMS for the waste and water technology solutions. I have also learned that making phone calls and sending e-mails of inquiry are sometimes necessary in order to create a technical solution.

Adjetey, Sensing

Starting this internship, I was assigned the role of being 'in charge of sensors'. I was curious as to what this role would involve; I researched the area in question and prepared well for this internship position since the only experience I had with sensors, was in my semester-long robotics class. In only 10 weeks, I have grown to love this iSTEP internship. It has prepared me to function and excel in a culturally diverse, multi-talented, and globally distributed team. Apart from learning how to work beyond the scope of job titles, I have adopted the skill of effectively communicating in team discussions. All in all, this summer experience has opened my eyes to more things than I can share in writing.

Kanba, Visualization

My role for this internship was to develop the visualization for the technology solutions so that Ashesi's operations department can interface with the Ashesi Resource Tracker system with ease. It was a good experience; absolutely.

9.2 TechBridgeWorld Reflections

Since TechBridgeWorld was founded in 2004, we have been offering CMU students several opportunities to learn and participate in the field of ICTD, including courses, independent studies and seminars. However, students have been consistently expressing interest in a summer opportunity which combined research with impact in developing community settings. In 2008, we began designing an innovative internship that enhances participation and education in ICTD through guided research projects in underserved communities. In summer 2009, iSTEP was launched.

In the past four years of the iSTEP internship program, TechBridgeWorld has had the opportunity to train and mentor four teams of talented and passionate CMU students to conduct ICTD research. Furthermore, through iSTEP, we had the opportunity to collaborate with extaordinary partners in Tanzania, Bangladesh, Uruguay and Ghana. The iSTEP projects have resulted in research contributing to the fields of assistive technology, education, literacy, information exchange, as well as environmental sustainability. Furthermore, faculty and staff from TechBridgeWorld and iSTEP alumni had the opportunity to present iSTEP outcomes at the ICTD 2010 conference in the United Kingdom.

We look forward to collaborating with iSTEP alumni to publish and present iSTEP outcomes in future ICTD-related conferences.

The iSTEP internship program is designed to be a guided learning experience for students, yet it has proven to be a valuable learning experience for the TechBridgeWorld team. Every year, we conduct end-of-internship student surveys and have follow-up conversations with partners to learn how we can improve the internship program for the future. As a result, the iSTEP program evolves every year based on their feedback.

While iSTEP is a rigorous and rewarding internship experience for students, it is the same for TechBridgeWorld. It is especially rewarding to read from the surveys the different ways every student grew through their experience with the program. iSTEP alumni even keep in touch with TechBridgeWorld from time to time and several have contributed to our annual fundraising campaign which supports future iSTEP internships. Now that some of the iSTEP alumni have been working for some time, we often hear from them about how iSTEP has helped them in their profession.

The TechBridgeWorld team looks forward to continuing the internship program and training the next generation's leaders. Our goal is that through their experience with our iSTEP internship program, these leaders will make informed decisions that benefit those in underserved communities, whether it is directly or indirectly.

9.3 Dissemination Outcomes

The Dissemination Coordinator managed the dissemination of the team's project and experience to appropriate audiences, which included the daily management of the team's various media initiatives, and the management and production of the final report and presentation. For the majority of the internship, the Dissemination Coordinator worked from Pittsburgh and coordinated with teammates in Berekuso to ensure effective communication and cohesion. Web tools such as Skype, Google Docs and DropBox were utilized during the internship. Furthermore, in weeks eight and nine of the internship, the Dissemination Coordinator traveled to Berekuso to assist the team in its fieldwork, documentation, and work at Ashesi. The following section details the outcomes of the iSTEP 2012 team's dissemination efforts.

Social Media

Social media was primarily used to engender a positive web presence and target larger audiences and similar groups working on relevant projects. The team's website featured the team's blog, as shown in Figure 34, which was updated approximately 5 times per week, with each team member blogging approximately once per week. The blog also featured guest posts from Ashesi students. The blog featured 60 entries, which garnered a total of 2,834 views (July was the busiest month with 1,157 views), 43 comments and 9 blog followers during the internship.

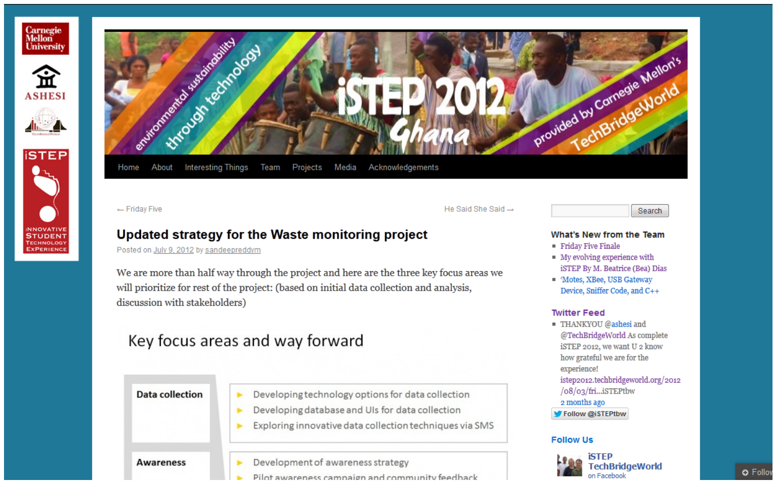


Figure 34. iSTEP 2012 Blog

Furthermore, the Dissemination Coordinator updated the iSTEP Facebook (Figure 35) and Twitter (Figure 36) accounts daily with updates from the internship. These included links to the latest blog entries or newly uploaded pictures and videos. By the end of the internship, the iSTEP Facebook page garnered 748 unique Timeline views and 109 unique Photos views. The majority of viewers were from the US and Ghana and the majority of viewers were between the ages of 18 and 34. For Twitter, we gained 36 followers since the start of the internship including Ashesi and Ashesi President Patrick Awuah. Furthermore, our updates garnered 27 re-tweets. Among those were re-tweets from Ashesi, CMU's Heinz College, and CMU-Q.

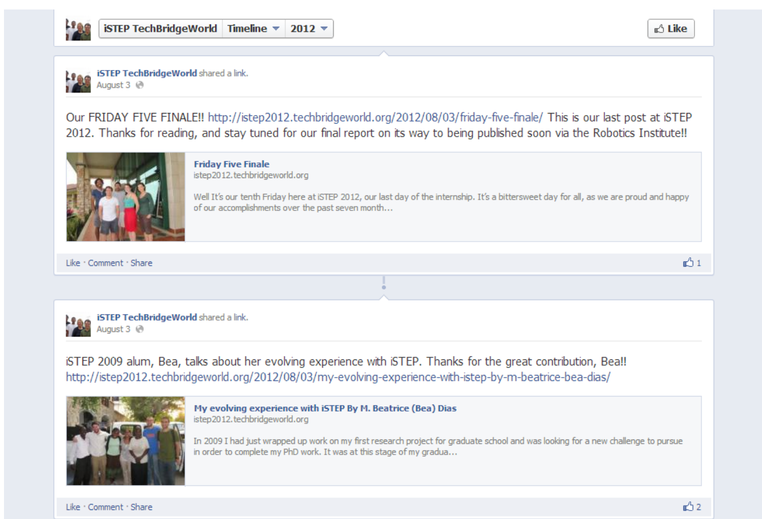


Figure 35. iSTEP Facebook Page

Figure 36. iSTEP Twitter Page

Lastly, YouTube (Figure 37) and Flickr (Figure 38) served as video and photo hosting websites, respectively, that enabled the team to share media. During the internship, three videos were posted on YouTube. "Akwaaba! From Ghana, iSTEP 2012 Introduction," which posted on June 8, garnered 106 views and 3 likes. "Women in ICT," which posted on July 7, garnered 101 views and 1 like. When the Dissemination Coordinator was in Ghana, she filmed "iSTEP 2012 Reflections," which was posted on July 31 and garnered 40 views and 3 likes. During the internship, the team posted three photo albums on Flickr, which garnered a total of 32 views. Most photos from the internship were posted on the iSTEP Facebook Page, which was more successful in its reach, with a total of 109 views.

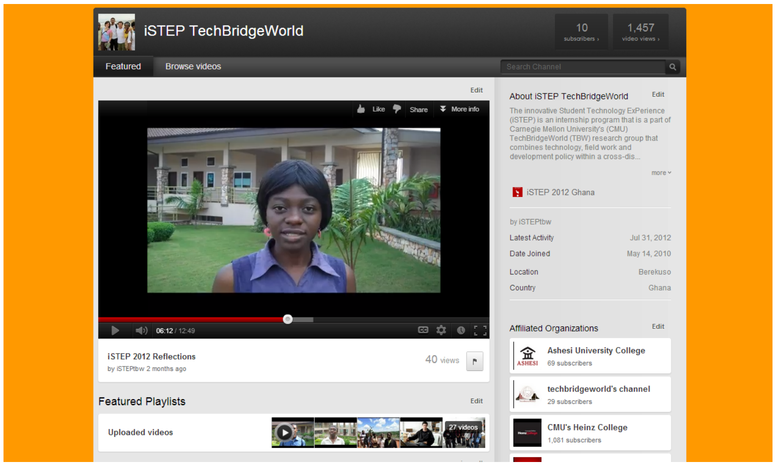


Figure 37. iSTEP YouTube Page featuring the iSTEP 2012 Reflections video

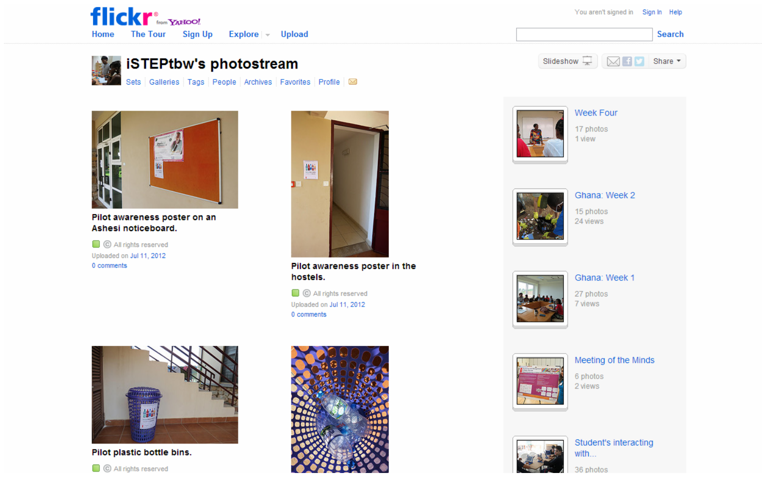


Figure 38. iSTEP Flickr Page

As mentioned, the Dissemination Coordinator spent the majority of the internship working from CMU's Pittsburgh campus. This worked well for assisting the team in Berekuso in contributing to the social media sites. Although distance was an added challenge to the project, the team worked to find solutions to connect across time-zones and internet connection. During high-traffic hours at Ashesi when many users were logged in to the internet at once, the connection speed and capability was not always reliable. It would often be difficult to post on the blog or upload footage with these difficulties. As a result, the team sent blog post text to the Dissemination Coordinator, who was able to post the entries to the blog. This method was similarly followed for uploading status updates, photos and videos to the other social media sites.

Evaluation

While the Dissemination Coordinator was in frequent communication with the team regarding social media efforts, at the middle of the internship, she evaluated the team's progress and sent feedback to each team member. This included a snapshot of their work done to date as well as strengths and suggestions to keep in mind for the remainder of the internship. This mid-internship evaluation added to the overall success of the team's social media dissemination efforts.

Other Communication Channels

In addition to social media, the Dissemination Coordinator worked with the team on other strategies for reaching other audiences. These included targeted e-mails and a media kit.

The team published five bi-weekly emails to almost 60 subscribers consisting of iSTEP 2012 advisors, family and friends. These bi-weekly e-mails were more detailed than information posted on the blog and social media channels due to the audience type and the communication frequency. The bi-weekly e-mails featured a student spotlight (both CMU and Ashesi students were featured), a link to a new iSTEP video, and a detailed update on their professional and personal endeavors from the past two weeks. The team also sent "VIP" e-mails. These e-mails were sent to key members of the CMU community, including the university president, college deans, department advisors, etc. The first VIP e-mail was sent midway through the internship and summarized the first half of the internship. The last e-mail was sent at the end of the internship and summarized the second half of the internship and the technology solutions. The interns received several encouraging replies from VIP e-mail recipients.

The Dissemination Coordinator also put together a media kit (Appendix VIII) for the iSTEP 2012 internship. This kit was created to capture and summarize aspects of the internship in a visual way that would allow for different media outlets to learn more about iSTEP 2012. The kit includes information on the iSTEP internship program, the iSTEP 2012 team of CMU and Ashesi students, the iSTEP 2012 projects, and student testimonials.

Final Report and Presentation

The Dissemination Coordinator led the team's efforts in producing a final report capturing the different aspects of the internship and its outcomes. This report was published as CMU Robotics Institute Technical Report. Furthermore, the iSTEP 2012 team (both CMU and Ashesi students) gave a final presentation to a public audience at Ashesi. Students, staff, and faculty (including Ashesi President, Patrick Awuah) attended the presentation to learn about the water and waste projects and ask questions, and were thanked by the CMU and Ashesi interns for their support.

10. CONCLUSIONS AND FUTURE WORK

The initial needs assessment activities have spanned just over three weeks, excluding activities undertaken before interns arrived in the field. The process has been successful and informative. The team now has a clear understanding of current conditions, needs and goals of the Ashesi community in regard to waste and water issues. From the leadership to the contractors that work with the university, members of the community appear to have a vision of a beautiful, environmentally-sustainable campus. To obtain this vision, technological collaboration is desired to implement data in decision-making and issue awareness generation.

Working with Ashesi University College is an exciting opportunity for the iSTEP team members and we believe such a partnership has the potential to create real value, not only in Ashesi's water system but in thinking about water systems throughout rural areas in Sub Saharan Africa. Ashesi, with its commanding technological edge over peer institutions in the region and unique desire to create a sustainable water system, is an ideal incubator space for thinking about cleaner, more sustainable, cost-effective and responsible water management systems. While the primary purpose of the iSTEP team is to improve Ashesi's water monitoring and management, we believe, if the work is done rigorously and effectively there is a strong likelihood the lessons learned at Ashesi will be applicable to the broader development community.

Ashesi is a dynamic institution, with the technological capacity, ethical standards, and environmental sustainability that makes it a leading figure in the future of West Africa and beyond. We are honored to have had the privilege to work with such a pivotal university in the development of Ghana. We hoped to bring our own commitment of high ethical standards, best practices, technological advancement and sustainability to the internship and its goals. We knew that we not only contributed our help with waste and water monitoring and water management, but also gained a lifetime of experience that will impact us as much as it impacts our partners.

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Appendices

Appendix I: Description of the biogas plant

Black water enters a decomposition chamber where methane is created the decomposition process and runs ups to a collection "balloon" near the kitchen's serving area. Biogas is designed to augment kitchen gas use which is currently one 89kg container every three days. It estimated that about 140,000m3 of biogas per year are obtainable at current consumption, which will substitute the equivalent of 5500 kg of LPG per year (*this is based on campus size of 1,000). Alternatively, Ashesi would also have the potential to generate about 22800KWh electricity supply from the biogas plant for 12 hours per day to supplement power demand, particularly during power outages. These estimates are from Ashesi's Environmental and Social Impact Evaluation report but these figures are from 2009 and I do not believe they accurately reflect actual methane production based on my conversations with the environmental engineer. Within needs assessment we are trying to get an accurate picture of what gas use in the kitchen will look like as the campus grows. Most estimates assume linear growth with unchanging per capita fuel needs, however we think kitchen efficiencies likely imply decreased per person fuel consumption. If so, then as the campus grows the biogas tank will provide an increasing percentage of kitchen fuel needs.

Figure 1. Biogas "Balloon"

Appendix II: Tank and Pipe Sizes

Tank Sizes

TANK	INSIDE DIMENSION			QTY	VOLUME	LITIRES	GALLONS
	W(m)	L(m)	H(m)		(m3)		
Rainwater tanks Dorm Block 1	3.1	5.7	2.4	4	169.6	169,632	37,770
Rainwater tanks Dorm Block 2	3.1	5.7	2	4	141.4	141,360	31,400
Admin rainwater (main Tank)	5.2	6.1	2.4	1	76.1	76,100	16,900
Fire Tank	-	-	-	-	-	-	-
Main Tank	3	5.7	2.25	2	76.95	76,950	17,100

Pipe Sizes[1]

Conversions [1”=25mm]
Mains
Borehole—50mm HDPE
Rainwater to main tank—50mm PVC
Cold water from main tank to buildings—75mm PVC
Cold water around the buildings—32mm PVC
Cold water to buildings—25mm PVC
Waste/Fire
waste pipe (sinks)—100mm PVC
Waste pipe (toilets)—150mm PVC
Fire Hydrants—100mm PVC
Hose reel pipe—50mm PVC
Internal
Toilets—13mm PVC
Urinals—13mm PVC
Sink—13mm PVC
Soil—100mm PVC
Waste—32 and 50mm PVC

Appendix III: Assessment Materials

This section includes:

- Needs Assessment survey
- Pre-intervention survey
- Post-intervention survey
- End user testing forms

Needs assessment survey

Environmental practices at Ashesi University College in Ghana

There are 18 questions in this survey.

Survey ID #

1 Please enter your unique survey ID number. This is the number provided on the consent form confirmation page. * Please write your answer here:

Demographics

2 Which of the following best describes you? * Please choose **only one** of the following:

- ☐ Student - Freshman
- ☐ Student - Sophomore
- ☐ Student - Junior
- ☐ Student - Senior
- ☐ Faculty
- ☐ Staff
- ☐ Other

3 Do you live on campus? * Please choose **only one** of the following:

- ☐ Yes
- ☐ No
- ☐ Other

Waste

4 Which items do you dispose of on campus? * Please choose all that apply and provide a comment:

- ☐ Plastic bottles
- ☐ Polythene bags
- ☐ Plastic sachets/wrappings
- ☐ Other plastic items, please specify:
- ☐ Sheets of paper
- ☐ Newspaper
- ☐ Books
- ☐ Paper sachets/wrappings
- ☐ Paper or cardboard boxes

- ☐ Other paper items, please specify:
- ☐ Metal/tin cans
- ☐ Metal/tin containers
- ☐ Metal/tin wrappings
- ☐ Electronics
- ☐ Other metal/tin items, please specify:
- ☐ Glass bottles
- ☐ Light bulbs
- ☐ Other glass items, please specify:
- ☐ None of the above

5 How do people generally dispose of items on campus? * Please choose **all** that apply:

- ☐ Put in bin
- ☐ Throw on ground
- ☐ Recycle
- ☐ Other:

6 When you need to throw something away on campus, how easy is it to find a bin? *
Please choose **only one** of the following:

- ☐ Very easy
- ☐ Somewhat easy
- ☐ Not easy

7 During an average week, how often do you purchase meals from the campus cafeteria/dining hall? * Please choose **only one** of the following:

- ☐ Never
- ☐ Sometimes
- ☐ Always
- ☐ Other

8 How knowledgeable are you about recycling in general? * Please choose **only one** of the following:

- ☐ Very familiar
- ☐ Somewhat familiar
- ☐ Not familiar

9 How important is recycling to you? *
Please choose **only one** of the following:

- ☐ Very important
- ☐ Somewhat important
- ☐ Not important

10 Are you aware of any recycling efforts on campus? *
Please choose **only one** of the following:

- ☐ Yes, please specify in the comment box.
- ☐ No

Make a comment on your choice here:

11 Do you personally recycle on campus? * Please choose **only one** of the following:

- ☐ Yes
- ☐ No
- ☐ Other

12 How effective are current trash disposal efforts on campus? (Location and availability of bins, trash collection schedule, policies, etc.) *
Please choose **only one** of the following:

- ☐ Very effective
- ☐ Somewhat effective
- ☐ Not effective

Water

13 Do you know from what sources Ashesi obtains its water on campus? * Please choose **only one** of the following:

- ☐ Yes, please list in the comment box.
- ☐ No

Make a comment on your choice here:

14 On campus, how do you personally use water? *
Please choose **all** that apply:

- ☐ Drinking

- ☐ Cooking
- ☐ Bathing
- ☐ Toilet/WC
- ☐ Laundry/Washing
- ☐ None of the above
- ☐ Other:

15 How knowledgeable are you about water conservation in general? *
Please choose **only one** of the following:

- ☐ Very familiar
- ☐ Somewhat familiar
- ☐ Not familiar

16 How important is water conservation to you? *
Please choose **only one** of the following:

- ☐ Very important
- ☐ Somewhat important
- ☐ Not important

17 Have you seen any instances of wasteful water practices on campus? *
Please choose **only one** of the following:

- ☐ Yes, please specify in the comment box.
- ☐ No

Make a comment on your choice here:

18 In which of the following ways would you be interested in supporting the University's environmental sustainability and resource management goals? *
Please choose **all** that apply:

- ☐ Join a student environmental group
- ☐ Segregate my own trash into available recycling bins on campus
- ☐ Reduce my water usage on campus
- ☐ Engage in awareness campaigns in the campus community
- ☐ None of the above
- ☐ Other:

Submit your survey.
Thank you for completing this survey.

Pre-intervention survey

iSTEP Pre-Intervention Survey Ashesi University College in Ghana

1. Which best describes you? *Please choose **only one** of the following:*
   - ☐ Ashesi student ☐ Staff ☐ Other: ________________
   - ☐ Visiting student ☐ Faculty

2. Are plastic bottles recyclable? *Please choose **only one** of the following:*
   - ☐ Yes ☐ No

3. Do you recycle plastic bottles on campus?
   *Please choose **only one** of the following:*
   - ☐ Yes ☐ No

4. Have you seen any posters about plastic bottles on campus?
   *Please choose **only one** of the following:*
   - ☐ Yes If yes, where? ______________
   - ☐ No

5. Is toilet paper flushable?
   *Please choose **only one** of the following:*
   - ☐ Yes ☐ No

6. What other items are flushable?
   Please list. ____________________________________

7. Do you flush toilet paper on campus?
   *Please choose **only one** of the following:*
   - ☐ Yes If yes, why? ____
   - ☐ No If no, why? ____

8. Have you seen any posters about flushing toilet paper on campus?
   *Please choose **only one** of the following:*
   - ☐ Yes If yes, where? _______________
   - ☐ No

9. Compared to others on campus, would you consider the amount of water you use to be:
   *Please choose **only one** of the following:*
   - ☐ More than others
   - ☐ About the same as others
   - ☐ Less than others

10. If you knew what proportion of the school's water you use regularly, would you:
    *Please choose **only one** of the following:*
    - ☐ Use a greater amount
    - ☐ Use the same amount
    - ☐ Use a smaller amount

11. How do you prefer to be informed about campus issues?
    *Please choose **only one** of the following:*
    - ☐ Ashesi email account ☐ Posters ☐ Word of mouth
    - ☐ Ashesi website ☐ Social media ☐ Notice boards

12. Which social media site do you use most?
    *Please choose **only one** of the following:*
    - ☐ Twitter
    - ☐ Facebook
    - ☐ Other: _____________________

Thank you for your participation.

Post-intervention survey

iSTEP Post-Intervention Survey Ashesi University College in Ghana

Over the past 2 weeks the iSTEP team has run a waste pilot program. This involved placing mesh bins around the school to collect plastic bottles and placing informational posters about toilet paper disposal in the bathrooms. Please take a few minutes to answer the following questions:

1. Which best describes you? Please choose **only one** of the following:
   ☐ Ashesi student ☐ Staff ☐ Other: ________________
   ☐ Visiting student ☐ Faculty
2. Are plastic bottles recyclable?
   *Please choose **only one** of the following:*
   ☐ Yes ☐ No
3. Do you recycle plastic bottles on campus?
   *Please choose **only one** of the following:*
   ☐ Yes ☐ No
4. Have you seen any posters about plastic bottles on campus?
   *Please choose **only one** of the following:*
   ☐ Yes If yes, where? ____
   ☐ No
5. How noticeable are the posters for plastic bottles?
   *Please choose **only one** of the following*:
   ☐ Very noticeable
   ☐ Somewhat noticeable
   ☐ Not noticeable at all
6. How easy is it to understand the plastic bottle posters?
   *Please choose **only one** of the following*:
   ☐ Very easy
   ☐ Somewhat easy
   ☐ Not at all easy
7. How easy is it to locate the mesh bins for collecting plastic bottles?
   *Please choose **only one** of the following*:
   ☐ Very easy
   ☐ Somewhat easy
   ☐ Not at all easy
8. Is toilet paper flushable?
   *Please choose **only one** of the following*:
   ☐ Yes ☐ No
9. What other items are flushable?
   Please list. ____________________________________
10. Have you seen any posters about flushing toilet paper on campus?
    *Please choose **only one** of the following:*
    ☐ Yes If yes, where? _______________
    ☐ No
11. Did you flush toilet paper on campus before the pilot program?
    *Please choose **only one** of the following*:
    ☐ Yes If yes, why? ____
    ☐ No If no, why? ____
12. After seeing the posters about toilet paper, do you flush toilet paper?
    *Please choose **only one** of the following:*
    ☐ Yes
    ☐ No

A

13. How easy is it to understand the tissue paper posters?
    *Please choose **only one** of the following*:
    - ☐ Very easy
    - ☐ Somewhat easy
    - ☐ Not at all easy

14. How did you become aware of the pilot program?
    *Please choose **all** that apply:*
    - ☐ E-mail
    - ☐ Poster
    - ☐ Word of mouth

15. The iSTEP team sent out an update mail about the results of the plastic bottle pilot program (on Monday, 15th July). Did you receive this update mail in your Ashesi Outlook account?
    *Please choose **only one** of the following*:
    - ☐ Yes
    - ☐ No
    - ☐ I haven't checked my e-mail

16. In your opinion, how would you describe the update email?
    *Please choose **all** that apply*:
    - ☐ Informative ☐ Uninformative
    - ☐ Motivating ☐ Unmotivating
    - ☐ Exciting ☐ Boring

17. How would you prefer to be informed about future environmental programs?
    *Please choose **only one** of the following:*
    - ☐ Ashesi e-mail
    - ☐ Ashesi website
    - ☐ Separate website for environmental activities
    - ☐ Facebook/other social networking sites

18. Any further feedback about the pilot program

    ____

    ____

Thank you for your participation.

End user testing forms

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
August 1, 2012

Researcher:	Date:	Time: ___:___☐AM ☐PM
User name:	Phone brand:	Model:
Position:	Keyboard: ☐Alpha-numeric ☐QWERTY ☐Touchscrn	
Phone number:	Signal: ☐Strong ☐Weak ☐Not available	
Location of SMS testing:	☐ Indoors ☐Outdoors	

SMS Input Software

CRITERIA	METRIC	COMMENTS
1. COST		
	Carrier: Cost per message to same carrier: Cost per message to other carrier: Phone set cost:	
	Total SMS cost per round (without errors):	
2. USABILITY		
	Time start: / Time end:	
	Input: 1: 2: 3: 4: 5:	Confirmation/error message 1: 2: 3: 4: 5:
	Time to complete one round of data collection on field:	
	Number of SMS submissions: Number of user errors:	
		Most common/recurring errors: ☐Formatting ☐Mistype ☐Misread number ☐Naming ☐Other ____________________
		On a scale of 1-5 (1= not at all easy and 5= very understandable)
	How easy is it to format an SMS data reading?	1 | 2 | 3 | 4 | 5
		What is difficult about formatting the SMS?
3. FUNCTIONALITY		
	Number of SMS received by CMS:	
	How understandable is confirmation message? (Does user understand that the message transmission has been successful, or that it contains an error	On a scale of 1-5 (1= not at all understandable and 5= very understandable) 1 | 2 | 3 | 4 | 5

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
August 1, 2012

	and how the error can be corrected)?					
		How do you interpret these/this message/s?				

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
August 1, 2012

Content Management System			
CRITERIA	**METRIC**		**COMMENTS**
1. USABILITY & FUNCTIONALITY	Start time:	End time:	
Time to input round of data entries manually	Number of data points input: 3 Data point 1: Data point 2: Data point 3: Time to complete one round of input:		
Number of user errors per round of data input			
Number of user errors per main functions			
Adding location	Prompt (read verbally to user) Location name: *Canteen* User input Location name input: Short code created: Location added correctly? ☐Yes ☐No If no, what is the error?		What is/are the user error/s? Program error/s: ☐Yes ☐No If yes, which?

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
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<table>
<tr><td>Adding sensor</td><td><u>Prompt (read verbally to user)</u>
Resource measured: Water
Location: Canteen
Number: 01

<u>User input</u>
Sensor name input:
Sensor added correctly?
☐Yes ☐No
If no, what is the error?</td><td colspan="5">What is/are the user error/s?

Program error/s: ☐ Yes ☐No
If yes, which?</td></tr>
<tr><td>Adding reading</td><td><u>Prompt (read verbally to user)</u>
Reading: 703
Sensor: Canteen 01
Date: Today's date

<u>User input</u>
Reading:
Sensor:
Date:
Reading added correctly?
☐Yes ☐No
If no, what is the error?</td><td colspan="5">What is/are the user error/s?

Program error/s: ☐Yes ☐No
If yes, which?</td></tr>
<tr><td>Ease of each function</td><td></td><td colspan="5">On a scale of 1-5 (1= not at all easy, 5= very easy)</td></tr>
<tr><td></td><td>How easy is it to add a location?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>How easy is it to add a sensor?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>How easy is it to add a reading?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td colspan="5">Please tell me about your over all experience with the content management system.</td></tr>
<tr><td></td><td></td><td colspan="5">What other features would be useful in this content management system?</td></tr>
<tr><td></td><td></td><td colspan="5"></td></tr>
</table>

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
August 1, 2012

<table>
<tr><th colspan="7">Visualization User Interface</th></tr>
<tr><td>1. USABILITY & FUNCTIONALITY</td><td></td><td colspan="5"></td></tr>
<tr><td>Number and type of user errors and program errors while querying specific data</td><td></td><td colspan="5"></td></tr>
<tr><td>Query 1</td><td><u>Data to be queried</u>
Date start: June 1 Date end: July 31
Resource type: Waste
Location: Hostel
Sensor: 01, 02</td><td colspan="5">Number of user errors in query:
What is/are the user error/s?

Number of program errors in output:
What is/are the program error/s?</td></tr>
<tr><td>Query 2</td><td><u>Data to be queried</u>
Date start: May 30 Date end: July 27
Resource type: Water
Location: Admin.
Sensor: 01</td><td colspan="5">Number of user errors in query:
What is/are the user error/s?

Number of program errors in output:
What is/are the program error/s?</td></tr>
<tr><td rowspan="2">Ease of querying data</td><td></td><td colspan="5">On a scale of 1-5 (1= not at all easy, 5= very easy)?</td></tr>
<tr><td>How easy is it to query data?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td></td><td colspan="5">What did you like about the application?</td></tr>
<tr><td></td><td></td><td colspan="5">What is difficult about querying the data?</td></tr>
</table>

End User Testing Form
iSTEP 2012: Water monitoring and management and waste management at Ashesi University College, Berekuso, Eastern Region, Ghana
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Ease of understanding graph output		On a scale of 1-5 (1= not at all easy, 5= very easy)				
	How easy is it to understand the graph output?	1	2	3	4	5
Axes, units, labels, colors		What do you like about the graph?				
		What is difficult about understanding the graph?				
	How easy is it to locate key features?	On a scale of 1-5 (1= not at all easy, 5= very easy)				
		1	2	3	4	5
Layout, format, maneuverability, intuitiveness	How easy is it to navigate the user interface?	On a scale of 1-5 (1= not at all easy, 5= very easy)				
		1	2	3	4	5
		What is easy about navigating the user interface?				
		What is difficult about navigating the user interface?				
Value of side panel links		On a scale of 1-5 (1= not at all useful, 5= very useful)				
	How useful is the Water Quality link?	1	2	3	4	5
	How useful is the Waste Monitoring link?	1	2	3	4	5
	How useful is the Ashesi Water System link?	1	2	3	4	5
	How useful is the Ashesi Waste System link?	1	2	3	4	5
		What other features would be useful in the application?				

Appendix IV: Waste Audit Results

Collection point 1 produced five 240-liter big garbage bins weighing 44.5 kgs in total. Tissue paper, white paper, plastic bags, organic waste, plastic bottles and non-recyclable paper constituted the top five major forms of trash collected in the administration building. The results are presented below (Table 1):

No	Type of waste	Number of bags	Weight (kg)	Percentage by weight	Percentage by volume
1	White paper	2	4.5	10.1%	6%
2	Colored paper				
3	Tissue paper	8	16.5	37.1%	24%
4	Paper cups	1	1	2.2%	3%
5	Plastic bottles	4	3	6.7%	12%
6	Plastic sachets	2	1.5	3.4%	6%
7	Plastic bags	6	4.3	9.7%	18%
8	Styrofoam	1	0.2	0.4%	3%
9	Glass	1	2	4.5%	3%
10	Electronic waste	1	1	2.2%	3%
11	Tins	1	1	2.2%	3%
12	Non recyclable paper	2	2.5	5.6%	6%
13	Organic waste	2	4	9.0%	6%
14	Cardboard	1	1	2.2%	3%
15	Other stuff	1	2	4.5%	3%
	Total	33	44.5		
	Number of bins	5			

Table 1. Analysis of waste at collection point 1 academic building

Collection point 2 produced five 240-liter big garbage bins weighing 199 kgs. Considering the nature of the waste produced, the bins containing organic waste were weighed and recorded. A detailed analysis of the type of organic waste was not conducted. Further, for the cardboard and plastic waste an approximation of the weights was considered for the purpose of the analysis. The majority of the waste at this collection point was organic waste. The results are presented below (Table 2):

No.	Type of waste	Number of bags	Weight (kg)	Percentage by weight	Percentage by volume
1	White paper	NA	NA	NA	NA
2	Colored paper	NA	NA	NA	NA
3	Tissue paper	NA	NA	NA	NA
4	Paper cups	NA	NA	NA	NA
5	Plastic bottles	NA	NA	NA	NA
6	Plastic sachets	NA	NA	NA	NA
7	Plastic bags	NA	5	2.5%	NA
8	Styrofoam	NA	NA	NA	NA
9	Glass	NA	NA	NA	NA
10	Electronic waste	NA	NA	NA	NA
11	Tins	NA	NA	NA	NA
12	Non recyclable paper	NA	NA	NA	NA
13	Organic waste	NA	189	95.0%	NA
14	Cardboard	NA	5	2.5%	NA
15	Other stuff	NA	NA	NA	NA
	Total		199		
	Number of bins	5			

Table 2. Analysis of the waste at the collection point 2 kitchen building

Collection point 3 produced nine 240-liter big garbage bins. Considering the nature of the waste produced, only three bins were analyzed and the results were extrapolated to nine bins. Also for the food waste, an approximation of the weights was considered. The results are presented below (Table 3).

No	Type of waste	Number of bags	Weight (kg)	Percentage by weight	Percentage by volume
1	White paper	3	1.5	1.4%	5%
2	Colored paper				
3	Tissue paper				
4	Paper cups				
5	Plastic bottles	12	12	11.5%	20%
6	Plastic sachets	3	0.3	0.3%	5%
7	Plastic bags	12	27	25.8%	20%
8	Styrofoam	12	12	11.5%	20%
9	Glass				
10	Electronic waste				
11	Tins	3	7.5	7.2%	5%
12	Non recyclable paper				
13	Organic waste	3	28.3	27.1%	5%
14	Cardboard	6	12.9	12.3%	10%
15	Other stuff	6	3	2.9%	10%
	Total	60	104.5		
	Number of bins	9			

Table 3. Analysis of the waste at the collection point 3 hostel building

Overall analysis of the waste from the audit at academic building, kitchen building and hostel building is presented below (Table 4):

Aggregate analysis

No	Type of waste	Admin (weight in Kg)	Kitchen (weight in Kg)	Hostel (weight in Kg)	Total weight (kg)	Percentage by weight	1	White paper	4.5		[redacted]
2	Colored paper										
3	Tissue paper	16.5			16.5	5%					
4	Paper cups	1			1	0%					
5	Plastic bottles	3		12	15	4%					
6	Plastic sachets	1.5		0.3	1.8	1%					
7	Plastic bags	4.3	5	27	36.3	10%					
8	Styrofoam	0.2		12	12.2	4%					
9	Glass	2			2	1%					
10	Electronic waste	1			1	0%					
11	Tins	1		7.5	8.5	2%					
12	Non recyclable paper	2.5		0	2.5	1%					
13	Organic waste	4	189	28.3	221.3	64%					

14	Cardboard	1	5	12.9	18.9	5%			
15	Other stuff	2		3	5	1%			
	Total				348			Number of bins	[redacted]

Table 4. Overall analysis of the waste collected

Based on the data collected, different categories of waste are classified into recyclable and non-recyclable. White paper, paper cups, plastic bottles, plastic sachets, tins, organic waste and cardboard were considered recyclable. Overall 272.5 kg of the 348 Kg of the waste by weight falls into the recyclable category, indicating a recycling potential of 78 %. Further classification of recyclable waste into paper (white paper, paper cups, cardboard), plastic (plastic bottles, plastic sachets), tin and organic categories is presented below (Table 5).

Category	Percentage of recyclables (weight)
Paper	10%
Plastic	6%
Organic	81%
Tin	3%

Table 5. Percentage of recyclables (by weight)

Appendix V: Sensor Options for Waste Monitoring

Sl No	Technology	Name of the Scale	Readout Type (digital /non digital)	Connectivity to PC (Yes/No)	Measurement capacity (Kgs)	Total cost (USD)	Weblink
1	RFID	Smartac RFID Extreme tags	Digital	Yes	NA		http://www.cascadeng.com/markets/rfid/systems.htm http://www.smartrac-group.com/en/applications-waste-management.php http://www.smartrac-group.com/en/success-stories-waste-management-city-of-cincinnati-and-grand-rapids.php
2	Bluetooth/wireless	FitScan® BC-590BT	Digital	Yes, through associated software	150	250	http://www.tanita.com/en/radio-wireless-scales/ http://www.tanita.com/en/bc590bt/ http://www.thecompetitiveedge.com/shop/item/123-productId.184549627_123-catId.176160809.html
3	Bluetooth/wireless	FitScan® HD-351BT	Digital	Yes, through associated software	200	210	http://www.tanita.com/en/hd351bt/ http://www.thecompetitiveedge.com/shop/item/123-productId.184549536_123-catId.176160809_123-xsltparam-page.specifications.html
4	Bluetooth/wireless	FitScan®HD-351ANT	Digital	Yes, through associated software	200	130	http://www.tanita.com/en/hd-351ant/ http://www.thecompetitiveedge.com/shop/item/123-productId.184550198_123-catId.176160848.html
5	Bluetooth/wireless	FitScan® HD-400F ANT	Digital	Yes, through associated software	200	80	http://www.tanita.com/en/hd400f/ http://www.3rresources.com/shop/item/123-productId.184550408_123-catId.176160809.html

6	Wireless (802.11b)	fitbitaria	Digital	Yes, through associated software	158	130	http://www.fitbit.com/product/aria/specs
7	Load cell based	Preciamolen Jet'FP P Pallet scale (load cell based)	Digital	Yes, wire to a display and needs an indicator	600		http://weighing.preciamolen.com/industrial-weighing/en/160/jet-fp-p-pallet-scale.html http://weighing.preciamolen.com/templates/1/documents/en/05-11-00-1FT.pdf
8	Load cell based	Preciamolen R2 Range weighing bars (load cell based)	Digital	Yes, wire to a display and needs an indicator	300		http://weighing.preciamolen.com/industrial-weighing/en/86/-r2-range-weighing-bars.html http://weighing.preciamolen.com/templates/1/documents/en/05-19-01-1FT.pdf
9	Load cell based	Preciamolen R1 GMS (load cell based)	Digital	Yes, wire to a display and needs an indicator	150		http://weighing.preciamolen.com/industrial-weighing/en/156/r1-gm-r1-gm-s-range.html http://weighing.preciamolen.com/templates/1/documents/en/05-09-00-1FT.pdf
10	Accessories (transmitters and indicators to be used with load	Preciamolen I 53 AM indicator	Digital	No			http://weighing.preciamolen.com/templates/1/documents/en/13-03-03-1FT.pdf
11		Preciamolen I 60-S PH indicator	Digital	No			http://weighing.preciamolen.com/industrial-weighing/en/274/i-60-s-ph-indicator.html
12		Preciamolen I 400 transmitter	Digital	Yes			http://weighing.preciamolen.com/templates/1/documents/en/04-32-10-1FT.pdf

13	cells-7,8,9)	Preciamolen I 400 programmable weight indicator	Digital	Yes			http://weighing.preciamolen.com/industrial-weighing/en/117/i-400-programmable-weighing-indicator.html
14	Load cell based	AMS	Digital	Yes	600	22	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
15	Load cell based	AME	Digital	Yes	50	12	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
16	Load cell based	AMT	Digital	Yes	3	67	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
17	Accessories (transmitters and boards to be used with load cells-14,15,16)	Smart metering pro board and Waspmote	Digital	Yes		153	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
18	Digital scales	Platform scales	Digital	No	600		http://www.atcoworld.com/products/weighing-scales-systems-industrial-scale-platform-scales.asp
19	Digital scales	Bench scales	Digital	No	300		http://www.atcoworld.com/products/weighing-scales-systems-hanging-scales-mechanical-bench-scales.asp
20	Digital scales	Richter Alpha bench scales	Digital	No	600	640	http://www.richterscale.co.za/Platform_%26_Bench.html
21	Digital scales	Industrial scales	Digital	No	2000		http://www.atcoworld.com/products/weighing-scales-systems-industrial-scale-heavy-duty-platform-scales.asp
22	Digital scales	Ohaus Champ™ CD-11 Floor	Digital	No	2500	3158	http://www.anascoscales.com/march04/image/platform/platalbum/pages/CD11FloorScale_jpg.htm

		Scales (load cell based)					
23	Digital scales	Accura	Digital	No	600	2895	
24	Digital scales	CS 500 - crane scale	Digital	No	500		http://www.ablescale.com.au/media/pdfs/product/cs_crane_scale.pdf
25	Dial scales	Camry Two Dial Platform Scale	Non digital	No	500		http://www.anascoscales.com/march04/image/platform/platalbum/pages/Floor%20Scale%20Base_jpg.htm
26	Dial scales	Camry Two Dial Platform Scale	Non digital	No	150		http://www.anascoscales.com/march04/image/platform/platalbum/pages/dialplatform2_jpeg.htm
27	Ultrasound for volume	XL-MaxSonar®-WRA1™	Digital	Yes	765 centimeters	116	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
28	Ultrasound for volume	LV-MaxSonar®-EZ0™	Digital	Yes	645 centimeters	37	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf
29	Accessories (to be used with ultrasound sensors-27,28)	Smart metering board and Waspmote	Digital	Yes		153	http://www.libelium.com/documentation/waspmote/smart-metering-sensor-board_eng.pdf

Appendix VI: SMS Input and Expected Output

SMS Input	Results
Proper Code and Value “WstHos04 65.7” or “wsthos04 65.7”	Reply SMS: “Waste input successful. Thank you!” Values are inserted to database
Improper Code “BadTry01 65.7” or “WstGym 65.7”	Reply SMS: “Sorry. Sensor code, 'BadTry01', is not correct. Check, and try again. Thank you.” Values are not inserted into database
Any message sent from unregistered phone number (not listed in database users table)	Reply SMS: “Sorry, you are not an authorized user. You cannot input data at this point. Thank you. << From: sms-to-database system. iSTEP 2012 >>” Values are not inserted into database
Lacking Value “WstHos01”	Reply SMS: “”
Extra Fields “WstHos01 65.7 89.0”	"Entry error detected. Hint: Please check your message spacing. Be sure to send only one entry per SMS text message"
Extra Characters “WstHos01 !65.7”	Reply SMS: “Sorry. Sensor reading, '!65.7’, is not numeric. Check, and try again. Thank you.”

Appendix VII: Waste Project Awareness Plan

Polythene/plastic bags

1. To encourage reusing of the plastic bags:

Method of awareness/strategy	Encouraging re-usage of plastic bags through exploring alternate options like paper bags, leather bags and plastic bags which can be recycled
Responsibility	Dean of Student and Community Affairs in coordination with the catering contractor and the stores
Examples/options	Option 1: Use of paper bags  **Figure 2. Paper bags - to be used in lieu of plastic bags** Link: http://www.nashvillewraps.com/shopping-bags/recycled-shopping-bags/c-001155.html Estimated price: USD 50 for 250 bags Option 2: Use of bags made from recycled sachets  **Figure 3. Bags made of recycled sachets - to be used in lieu of plastic bags**

<table>
<tr><td></td><td>
Link: http://www.trashybags.org/products.htm

Further, the university can also carry out source segregation of plastic sachets and partner with Trashybags for recycling.

Option 3: Use of plastic bags which can be recycled. Additional option of branding the bags can also be considered

Figure 4. Recyclable plastic bags - to be used in lieu of plastic bags

Link: http://www.reusethisbag.com/productslisting.aspx?mcid=108&pcid=108&ccid=109

Estimated price: USD 1.29 (for order of 1000 units) to USD 1.89 (for order of 200 units) for a tiny tote bag (8” x 5” x 10” with imprint area 5" wide by 5" high and made of 100 gram strong polypropylene with 14" handle).

Option 4: The convenience store on campus can offer discounts to personnel using plastic reusable bags. The reusable bags could come with a stamp card, which would be stamped with the convenience store’s special stamp for every use. When the stamp card is fully stamped, the store replaces it and offers a token gift.
</td></tr>
<tr><td>Target audience</td><td>All the stakeholders of Ashesi</td></tr>
</table>

1. To encourage reduction in use of plastic bags:

Method of awareness/strategy	It is a general practice to provide plastic bags for every purchase irrespective of the purchase. A practice of 'ask for bag' can be introduced to sensitize students and influence their behavior.
Responsibility	Dean of Student and Community Affairs in coordination with the kitchen and the convenience stores
Target audience	All the stakeholders of Ashesi

Water Sachets

1. To increase awareness about the water treatment system:

Method of awareness/strategy	Through video and communication via e-mail. At the start of every semester update the community with a brief video about the working of the water treatment system its capabilities.
Responsibility	Dean of Student and Community Affairs in coordination with the operations group
Target audience	All the stakeholders using Ashesi's water system

2. To increase awareness about the water testing system:

Method of awareness/strategy	Through posters and communication via e-mail. As the water testing is done on a monthly basis communicating the information/results of the tests will be helpful on a short term. Once a routine is established the reports can be posted on the website and the stakeholders can track the progress on the website.
Responsibility	Operations management in-charge of water testing.
Target audience	All the stakeholders using Ashesi's water system, especially students and staff

3. Increase bottle filling stations:

Method of awareness/strategy	Install water dispensing stations at key locations in hostels, academic and kitchen block. The dispensing stations will not only encourage the community to re-use the water bottles but also provide temperature controlled water. Further, the dispensing units can also be used as an

	advertising avenue to display fun facts about water usage like number of bottles filled, amount of Co2 conserved by recycling. Installation of dispensing units can also be clubbed with promotion of branded water bottles, which can be re-used by students and faculty. A total of 15 dispensing units (One dispensing unit on each floor and block of the hostels, 4-5 at key locations units in the academic building and 1-2 units in kitchen)
Responsibility	Operations management and development committee
Examples/options	Sample water refilling units (which require water supply/plumbing line):  **Figure 5. Sample waster dispensing unit with drinking water fountain** Link: http://www.globalindustrial.com/g/plumbing/drinking-fountains/water-refilling-stations/Elkay-Cooler-Kits?ref=t/PL/promo1 Estimated price: USD 1,000/unit (approximately) Other examples: http://www.globalindustrial.com/c/plumbing/drinking-fountains/water-refilling-stations?ref=cat/b/warer_refilling_stations Sample dispensing unit which does not require water supply/plumbing line:

	 Figure 6. Sample water dispensing unit with Link: http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=GXCF05D Estimated price: USD 200/unit (approximately) Other examples: http://products.geappliances.com/ApplProducts/html/GEAResults.htm#Category=Water_Dispensers Sample water bottles: Re-usable and branded  Figure 7. Sample re-usable and branded water bottle Link: http://www.theharvardshop.com/products/harvard-steel-water-bottle

	Awareness campaign about blocking the sale of bottled water: Central Michigan University, http://takebackthetapcmich.tumblr.com/ Awareness through social media/ video posts: http://www.youtube.com/watch?v=k9Hf1WOxfOg
Target audience	All the stakeholders using Ashesi's water system

Styrofoam

1. To increase usage of plastic boxes:

Method of awareness/strategy	Encouraging usage of plastic boxes through exploring options for easy cleaning
Responsibility	Dean of Student and Community Affairs in coordination with the catering contractor
Examples/options	Option 1: As the plastic boxes are expensive and can be used for a prolonged basis the Ashesi, as a starter, can procure a limited number (around 200) of plastic boxes and provide them to students for use. The boxes can be provided to the catering contractor and will be distributed to students who purchase food. However, the catering agency can collect a fee (around GHC 50 pesewa) for cleaning the plastic boxes once they are returned after use. This activity can be coupled with increase of the Styrofoam box prices from existing GHC 50 pesewa to GHC 1, to further push the use of plastic boxes and recycle them. Option 2: As the plastic boxes are expensive and can be used for a prolonged basis the Ashesi, as a starter, can consider subsidizing the plastic boxes to students. This activity can be coupled with increase of the Styrofoam box prices from existing GHC 50 pesewa to GHC 1, to further push the use of plastic boxes and recycle them (in this scenario students are responsible for the cleaning of plastic boxes).
Target audience	Ashesi's students and other stakeholders who buy food from the kitchen

2. Ban Styrofoam on campus completely :

Method of awareness/strategy	Through posters and videos thereby increasing awareness along with imposing a ban on sale of Styrofoam on campus. A policy for ban on sale of Styrofoam on campus can be developed and implemented.
Responsibility	Dean of Student and Community Affairs in coordination with the catering contractor
Examples/options	The ban on sale of Styrofoam can be accompanied by sale of low cost plastic boxes for collection of food. The boxes can be made available through the convenience store of the campus for the stakeholders.  **Figure 8. Sample plastic bottles to be used in place of Styrofoam** Estimated price: USD 1 for 1-3 units (approximately, in local currency and market)
Target audience	All the stakeholders of Ashesi

Paper

1. Encourage use of electronic documents:

Method of awareness/strategy	A considerable amount of assignments are submitted in paper. Going ahead, students can be encouraged to submit assignments online thereby reducing paper use. This will also help students to polish their documentation skills which will be helpful in their careers.
Responsibility	Dean of Academic Affairs
Examples/options	Using Courseware as the primary source of submission of notes, assignments and reports.
Target audience	Faculty and students

2. To increase options for double-side printing:

Method of awareness/strategy	Exploring options for installing printers capable of double side printing.

Responsibility	Dean of Student and Community Affairs in coordination with the IT department
Examples/options	Work closely with the IT team, facilities team and the development team for installation of double side printers in key locations like library and labs which are used frequently by students.
Target audience	All the stakeholders of Ashesi

Electronic Waste

1. Encouraging reduction in e-waste:

Method of awareness/strategy	Policies for usage of consumables like toners and ink cartridges
Responsibility	IT department
Examples/options	Using low quality printing option as the default option for all printing thereby reducing toner usage. Encouraging double side printing also helps is reduction on toner usage.
Target audience	IT department

2. Encouraging recycling of e-waste:

Method of awareness/strategy	Exploring options for recycling/reusing the consumables/cartridges
Responsibility	IT department
Examples/options	Tying up with local IT vendors for collection of used cartridges and reusing them. Considering that the volumes generated from campus are not high, the IT department in-charge of the consumables can collect and store the cartridges before attaining a significant volume for recycling.
Target audience	IT department

Plastic Bottles

1. To increase recycling through source segregation:

Method of awareness/strategy	As students are interested in source segregation, placing separate bins for collecting plastic bottles will result in separation of plastic bottles from the rest of the trash. Different strategies can be adopted

	for recycling of the plastic bottles collected through source segregation.
Responsibility	Dean of Student and Community Affairs in coordination with the operations group
Examples/options	Posters: **Figure 9. Sample poster for recycling plastic bottles** Strategy for recycling of plastic bottles: Option 1: Implement a pilot awareness and source segregation to collect information regarding the number of bottles collected. The data collected can be used to estimate the volume of storage space required to store the bins on a regular basis and send them to the plastic bottle recyclers in the Accra region, once suitable volumes are collected. Option 2: Implement a pilot awareness and source segregation to collect information regarding the number of bottles collected. Some of the members of the cleaning staff are known to collect the plastic bottles and the plastic bottles collected through pilot source segregation can be handed over to the cleaners for informal recycling.
Target audience	All the stakeholders of Ashesi

Cardboard

Method of awareness/strategy	Encouraging alternate use of cardboard boxes
Responsibility	Dean of Student and Community affairs and the stores
Examples/options	Using cardboard boxes for primarily collecting white paper in classrooms, as there are no dust bins in classes.
Target audience	Students

Tissue paper

1. Encouraging flushing of tissue paper:

Method of awareness/strategy	Posters in all the WCs
Responsibility	Dean of Student and Community Affairs in coordination with the operations group
Target audience	All the stakeholders of Ashesi

2. Discouraging wasting tissue paper:

Method of awareness/strategy	Posters in all the WCs
Responsibility	Dean of Student and Community Affairs in coordination with the operations group
Target audience	All the stakeholders of Ashesi

Appendix VIII: Media Kit

iSTEP 2012
SUSTAINABLE TECHNOLOGY

iSTEP 2012

innovative Student Technology ExPerience

-a summer internship program of TechBridgeWorld-

Projects

1. Waste Management

2. Water Monitoring and Management

Partner

Ashesi University College, Berekuso Ghana

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GHANA

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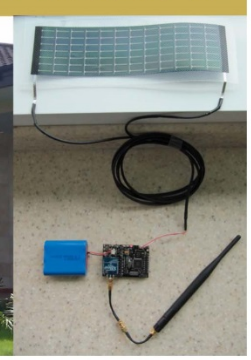


INNOVATIVE STUDENT TECHNOLOGY EXPERIENCE

The innovative Student Technology ExPerience (iSTEP) is a unique internship program that is a part of Carnegie Mellon University's (CMU) TechBridgeWorld (TBW) research group. iSTEP combines technology, field work and development policy within a cross-disciplinary team both at CMU and abroad. The iSTEP 2012 team travelled to Ghana to work with our partner, Ashesi University College (Ashesi), to implement two projects: **(1) a waste monitoring project** and **(2) a water monitoring and management project.** The CMU team prepared for the internship for 16 weeks in the Spring 2012 semester through a mini course and independent study. While the interns traveled to Ghana for ten weeks in Summer 2012 (with exception of one intern and one advisor who came to Ghana for just 2 weeks each), the advisors at TBW remained in Pittsburgh to collaborate as a globally-distributed team

TechBridgeWorld is a research group based in the Robotics Institute at Carnegie Mellon University, that develops and field tests sustainable technology solutions to meet development needs around the world. Founded in 2004 by Robotics Associate Research Professor Dr. M. Bernardine Dias, TechBridgeWorld pioneers research in the field of Information and Communication Technology for Development (ICTD).Since 2004, TechBridgeWorld has been developing strong bonds with partners in developing communities while enhancing the role of technology globally, just like their motto states they aim to develop, **"technology with a global heart."** Focusing on two main principles, sharing expertise to create innovative and locally suitable solutions and empowering local populations to create sustainable solutions, TechBridgeWorld creates accessible and relevant technology. TechBridgeWorld works closely with the community to address long-term challenges and to develop sustainable solutions. Through the knowledge and creativity of Carnegie Mellon faculty, staff, and students, TechBridgeWorld uses its technical expertise to help realize the community's vision of development.

Previous Projects

Each year iSTEP works on bringing innovative technologies to underserved communities. We work with a partner organization in the community to address local needs and challenges. Below speaks to the projects we have worked on in the past three years, since its first year in 2009, and our goals for the future.

2009 Tanzania

2009 marked the inaugural year for the iSTEP program. The team worked with the University Computing Center in Dar es Salaam on three projects:

1. Creating and evaluating culturally-relevant educational technology and games for child literacy.

2. A cell phone application for use by social workers to track information on services provided to AIDS orphans and vulnerable children.

3. Enhancing and evaluating a low-cost braille writing tutor for visually-impaired students.

iSTEP2009.techbridgeworld.org

2010 Bangladesh

1. Creating and evaluating culturally-relevant educational technology and games for students at the Asian University for Women's Access Academy.

2. Enhancing, localizing, and evaluating a low-cost braille writing tutor for visually-impaired students.

iSTEP2010.techbridgeworld.org

2011 Uruguay

1. OLPC/Computer Tool (OCT): Created a culturally relevant English literacy tool accessible on the OLPC and on regular laptop and desktop computers.

2. Facebook Tool (FBT): Created an engaging Facebook based tool for students to practice English literacy skills.

3. Content Authoring Tool (CAT): Created a Content Authoring Tool with an interface that is customized to the needs of English literacy experts in Uruguay

iSTEP2011.techbridgeworld.org

2013 and beyond

Future iSTEP locations potentially include Chile, India, Jordan, Macedonia, and Rwanda.

INNOVATIVE **STUDENT** TECHNOLOGY EXPERIENCE

5 Carnegie Mellon University Students and 7 Ashesi University College Students





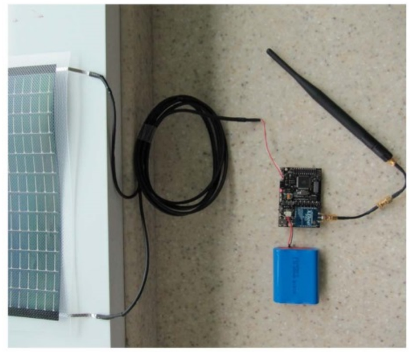
	Scott Andes	Corinne Clinch	Julie Mallis	Sandeep Reddy Munnangi	Ronnell Perry
Team Role	Project Manager Water Project	Software Developer	Dissemination Coordinator	Project Manager Waste Project	Assessment Coordinator Team Leader

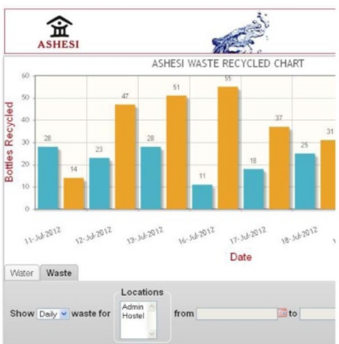




	Sonia Awedoba Adda	Juliana Esi Tanoa Botsio	Selase Attah Kwamuar	Diana Dayaka Osei	Maame Abena Owusu-Acheaw
Team Role	Needs Assessment Evaluation	Community Awareness	Data Gathering	Team Lead Dissemination	Long Term Strategy


	Nii Adjetey Sowah	Kanba Daniel Tapang
Team Role	Sensing	Visualization





The Waste Project

The Waste Monitoring project utilizes Waspmote sensors to send waste production readings to a database and user interface, in order to monitor the waste on campus.

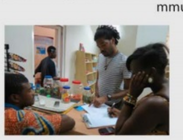
The Water Project

The Water Monitoring and Management project uses Waspmote technology to transmit water usage and rainwater levels to the same database system for monitoring and managing the water on campus.

Methods

After performing an in-depth needs assessment to become knowledgeable about the campus' current conditions, systems, behaviors and attitudes toward the issues of water and waste among campus community members, the iSTEP team developed the relevant technologies and systems to address the water and waste needs. This included solution brainstorming, prototype development, testing, and evaluation. The team approached field work from a participatory research framework with Ashesi being an integral partner that best articulated its priorities. The iSTEP team drew from the disciplines of anthropology, economics, public policy, civil engineering, computer science, and design to uniquely approach Ashesi's distinct challenges.

Before develiping the necessary technologies, our team conducts a formal needs assessment to better evaluate the concerns and needs of the community. We work with the community to develop culturally relevant technolgies and solutions.



INNOVATIVE STUDENT TECHNOLOGY EXPERIENCE

"The iSTEP 2012 projects are at the intersection of technology, policy and development – a unique experience offered only by TechBridgeWorld."

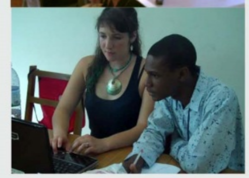
- "iSTEP helped me understand the importance of conducting thorough needs assessment, of working with a local community and of effectively evaluating the solutions brainstormed. The knowledge and know-how I have gained from iSTEP will enable me contribute to my country's [Ghana] development as I will continue to pursue my personal ICTD projects including the Readworm community library project and the Ghanaian sign language computer tutor project. " - Diana, Ashesi iSTEP intern
- My time in Ghana was as inspiring and intriguing as I expected it to be... I recognized the importance of being pro-active and persistent... I was impressed by my team members who started with [a dogged and hardworking] attitude and challenged me to follow it, and I'm thankful to have learned from them." -Corinne
- "On a couple of nights, apart from the moon, Ashesi was the only source of light for kilometers as it is nearly immune from power outages on the national electricity grid because of its generators... because Ashesi is the bearer of many resources such as abundant electricity and water, it must employ a greater management responsibility. iSTEP was invited to be here partly to give perspective on how that responsibility might be managed using technology... The structure of this internship gave me the opportunities to learn from teammates, TechBridgeWorld staff, and its network of research professionals."- Ronnell
- "I enjoyed the part where I started developing the Content Management System (CMS) for the technology solutions to the water and waste projects. I have also learned that making phone calls and sending e-mails of enquiry are an important aspect of creating a technical solution." -Selase
- "It was a good experience; absolutely." - Kanba, Ashesi iSTEP intern
- "ICTD, ICTD, ICTD. It's a great challenge to be working on an ICTD project; however, the CMU interns made it look so easy as they brought their experience and semester-of-preparation to bear on the projects. I would do iSTEP again because of my interest in ICTD. A great internship." - Diana, Ashesi iSTEP intern

Julie working in her Pittsburgh lab at CMU

The team conducting a meeting over Skype

The three Heinzers with advisor Nina overlooking the view from Ashesi

The entire team in Berekuso working in the library together on the projects



Ronnell

"iSTEP 2012 is requiring me to synthesize my competencies gained in school and life as a Peace Corps volunteer. Team work and communication is always the most challenging aspect of projects like this, but it also has the potential to be one of the most rewarding. Working with TechBridgeWorld this summer will be rigorous, but we have a lot of support from the people at CMU and at Ashesi University College in Ghana. I am ready for this."

Sandeep

"The iSTEP 2012 projects are at the intersection of technology, policy and development – a unique experience offered only by TechBridgeWorld. The team selected has a7h a partner like Ashesi, focused on environmental sustainability, the team hopes to make a long lasting impact on the community both in Ashesi in Ghana and in CMU."

Corinne

"I've always been interested in interdisciplinary work, and I'm excited to finally get involved and apply the academics I've been learning for years. ISTEP- and TBW-style collaboration will be making changes in developing countries for the years to come. "

Scott

On this project I learned the importance of thinking clearly about timelines in technology development projects and to consider tasks that may take longer than anticipated. I learned to be a flexible manager, and because the management role required leadership by consensus, to take the time to incorporate the team's ideas within project decisions.

Julie

Through this experience, I learned effective ways to move beyond the inherent challenges of working on a globally distributed team... Always staying cognizant of the time-zone difference helped to keep the multiple tasks I worked on efficient and strong... This experience has prepared me for what might be a future of freelance work, working with people on the West Coast, while staying on the East. Using Skype, Dropbox, and email... At this point, I feel prepared for anything.

#iSTEP (innovative Student Technology ExPerience) is a summer internship program of #TechBridgeWorld, a research group at Carnegie Mellon University that develops and field tests sustainable technological solutions to meet development needs around the world. Introduced in 2009, iSTEP is a unique experience that provides Carnegie Mellon students with the opportunity to conduct technology research projects in underserved communities.

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