PROJECT PORTFOLIO: Undergraduate Thesis

University of Virginia

School of Engineering and Applied Science

Water Purification in Rural South Africa: Ethical Analysis and Reflections on Collaborative Community Engagement Projects in Engineering

Service-Learning at SEAS: Analysis of Existing Opportunities and Recommendations for Improvement

Bachelor of Science in Chemical Engineering

April 30, 2009

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Executive Summary

This project initiated when I traveled to South Africa with Ana Jemec during the summer of 2008 to construct a water purification system in a rural community. My faculty advisor on the service-learning project, who became my technical advisor for this thesis project, was Robert Swap. He provided substantial assistance in planning for the project itself, reflecting on the experience, and compiling the technical report.

In my prospectus I planned to develop a framework describing the factors that are necessary for carrying out sustainable development projects in rural communities, including cultural and environmental factors, community participation, transparency, reciprocity, education, and maintenance. I intended for my project in South Africa to serve as a case study while I compared other projects, some that were successful and others that were not, to develop a framework and make recommendations for future service-learning projects.

My technical report consisted of a journal article that was published in the April 2009 issue of the International Journal for Service Learning in Engineering (IJSLE). A local student in the Global Sustainability Club at the University of Venda and a community member that we worked with were coauthors on the paper, which provided our South African partners with the incredible privilege of receiving international recognition for their work.

Since I had a rewarding experience in completing an independent undergraduate service-learning project, I wanted to facilitate that process for others and provide engineering students with the resources needed to carry out service-learning projects more effectively, especially as part of institutional programs within the engineering

school that are closely tied with the rest of the University. In my own project I encountered numerous obstacles throughout the planning and implementation stages, including difficulties in finding faculty advisors, securing funding, preparing myself with adequate courses, and taking culturally appropriate and sustainable actions on the ground. While those challenges and reflections were described in my technical report, my STS research paper addressed the broader dimensions of undergraduate service-learning opportunities and made recommendations for the School of Engineering and Applied Science (SEAS) to improve the preparation and resources that are currently available to students. To further support my argument, I conducted fifteen hour-long interviews with students, faculty, and administrators who have been in involved in service-learning projects to provide their reflections and recommendations. Only a small portion of their comments could be included due to space limitations, but my sincere hope is that within the next five to ten years, as SEAS continues to advance its service-learning opportunities, the suggestions in this STS research paper will no longer be needed. New students will then carry this vision even further.

These documents attest to my completion of the degree requirements by relating the technical aspects of engineering projects to the social, cultural, environmental, and ethical aspects. While the technical challenge was to design and implement a water purification system in a rural community and to reflect on this process in the form of a journal publication, I learned that there is a mutual interaction between the scientific, technological, and social elements of a system. Engineers are responsible for considering all of these issues in addressing global challenges.

Water Purification in Rural South Africa: Ethical Analysis and Reflections on Collaborative Community Engagement Projects in Engineering

A Thesis
in STS 402

Presented to

The Faculty of the
School of Engineering and Applied Science
University of Virginia

In Partial Fulfillment
of the Requirements for the Degree

Bachelor of Science in Chemical Engineering

By

Eric Harshfield

April 24, 2009

On my honor as a University student, on this assignment I have neither given nor received unauthorized aid as defined by the Honor Guidelines for papers in Science, Technology, and Society courses.

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(Full signature)

Approved ______________________________ (Technical Advisor)
Robert J. Swap, Department of Environmental Sciences

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Water Purification in Rural South Africa: Ethical Analysis and Reflections on Collaborative Community Engagement Projects in Engineering

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Abstract – **This paper presents a sustainable development project in which University of Virginia students collaborated with University of Venda faculty, Global Sustainability Club students, and local community members to address water problems in a village in the Venda region of the Limpopo Province, South Africa. The cohort's goal was to implement a sustainable and contextually appropriate water purification and distribution system. The authors present the design and constructed process for a slow sand filtration system intended to provide clean drinking water to most households in the community. They present and analyze the successes, failures, and ethical dilemmas encountered throughout project execution. Also, the authors assess the project based on three evaluation criteria for service learning projects and explore possibilities for follow-up through the collaboration between the University of Virginia and the University of Venda. The paper ends with a reflection examining aspects of engineering community engagement projects including site assessments prior to project implementation, project timeframes, and cross-cultural institutional collaborations.**

Index Terms – South Africa, student-led research, sustainable development, water purification.

INTRODUCTION

Approximately 1.1 billion people worldwide lack access to safe drinking water.[1] In the Limpopo Province of South Africa, one of the poorest regions in the country, only 32% of children have access to drinking water on site and 24% have access to basic sanitation.[2] Diarrheal diseases are the second highest cause of premature mortality for both adults and infants in this province.[3]

The broadly recognized Accreditation Board for Engineering and Technology's criteria for engineering programs[4] describes the importance of thinking on a global scale. Graduates of an accredited program must have "the broad education necessary to understand the impact of engineering solutions in a global and societal context" (3.h). One way that the University of Virginia (U.Va.) achieves this goal is through its long history of collaboration with universities and communities in Southern Africa, including over two decades of scientific cooperation in large regional programs such as the Southern African Regional Science Initiative known as SAFARI 2000.[5] This program was "a large scale environmental and remote sensing field campaign focused on land-atmosphere interactions"[6] that helped develop a community of trust between U.Va. and several southern African institutions of higher education. To expand the scientific momentum from efforts such as SAFARI 2000, the Southern African Virginia Networks and Associations (SAVANA) consortium was created using "multi-directional, experiential learning based on...three major principles...: relationship, respect and reciprocity."[7] The consortium has arranged "various modalities of collaborative research, education and outreach activities, including distance-learning, Summer Study Abroad courses, January Term Intensive preparatory courses, semester exchanges, graduate level fellowships, and year abroad teaching fellowships" with students from U.Va. and southern Africa.[8] The authors, who were intimately involved in multiple aspects of this research collaboration, used these existing connections to plan and execute the project described here.

CASE STUDY

In Venda, a rural area in the Limpopo Province of South Africa, many people live without access to clean drinking water. The municipality typically provides taps throughout rural communities but distributes water to these taps infrequently, sometimes only once or twice a month, thus failing to provide an adequate supply of potable water. The authors collaborated with their project partners at the University of Venda (Univen) to address water problems in one of the underserved communities in this region; their goal was to determine how to implement a sustainable and contextually appropriate system of water purification and distribution. A village in the Mutale River Valley was initially selected because of the previous connections to the community through SAVANA. U.Va. students had worked with Univen students on several engineering projects in this community since 2006, including biogas digesters, solar lighting, solar disinfection (SODIS), water filtration using moringa seeds, rainwater harvesting, and small-scale slow sand filtration at a pre-school. All of the projects, except for the solar panels, had not worked properly or had been abandoned by the community after the students left; these projects could not be called "successful" by the criteria presented later in this paper. The authors' water purification project was a concerted effort to apply lessons learned from the shortcomings of previous student projects and to develop a large-scale slow sand filtration system, inspired by the previously built slow sand filter at the pre-school, which would provide clean drinking water to the entire community.

In September of 2007, the authors began building off their past experiences to conceptualize the water purification project. Eric Harshfield had previously participated in a 10-day January term course, "Ethics, Protocols, and Practices of International Research," where U.Va. students worked with students from southern Africa to learn about issues in international research and write proposals for development projects. During the summer of 2007, he also enrolled in the study abroad course, "People, Culture, and Environment of Southern Africa," which is "an intensive introduction to the complexity of coupled human-natural systems of southern Africa."[9] After the study abroad experience, he remained in South Africa to work with Univen researchers on a study of traditional medicine. During the spring semester of 2007, Ana Jemec studied abroad at the Australian National University, where she gained experience working in cross-cultural settings. In addition, for two summers she had interned at an environmental engineering firm where she gained exposure to water resources and water quality analysis. The U.Va. authors coupled these past experiences with their technical chemical engineering backgrounds to begin the planning stages of the project. They partnered with Elias Ramarumo, who volunteered through the SAVANA consortium to coordinate activities for a portion of the summer study abroad course. Additionally, he helped arrange transportation and accommodation for U.Va. students working on projects in South Africa and has been essential in linking U.Va. students with potential local community partners. As a native to the area, he has been effective in working with community leaders to plan village visits and had helped U.Va. students execute their projects in a culturally sensitive manner. Finally, the authors collaborated with students from the Global Sustainability Club (GSC) at Univen, including coauthor Ofhani Makhado (Figure 1). The aim of this club is to empower local students to get involved in local development projects as well as to collaborate on projects with other groups. The authors worked with other GSC students to plan the household surveys and the initial water purification system design.

FIGURE 1
GLOBAL SUSTAINABILITY CLUB STUDENTS.
BOTTOM ROW (LEFT TO RIGHT): ELLY MBONENI, COAUTHOR OFHANI MAKHADO, HUMBU SIARULI
TOP ROW: IRENE MAKUYA, FHATUWANI MALAU, BLONDI NYANGO, AUDREY RAEDANI, GADISI NTHAMBELENI, DUNCAN NENGWENANI

Throughout the planning process, the authors met with several advisors, including Professor Robert J. Swap in Environmental Sciences and Professor Rosanne Ford in Chemical Engineering. The authors also sought advice from students that had previously completed projects, including members of Engineering Students Without Borders, and they regularly corresponded with Univen students and faculty. An in-depth analysis of the benefits and drawbacks of different types of water purification systems, including solar distillation, SODIS, ceramic pot filtration, fabric filtration, and slow sand filtration indicated that the latter was easiest to implement at the community-wide level and most likely to be effective and sustainable. Slow sand filtration is a relatively simple, affordable, and reliable technology in which water is purified as it passes through a bed of sand that sits on top of supporting gravel and an underdrainage system. At the surface of the sand, an active layer of schmutzdecke, which is made up of biological matter, breaks down the microorganisms and organic matter contaminants in the raw water. With every sand particle the water encounters as it continues through the sand, the process of adsorption further removes microorganisms and other contaminants. The resulting water that exits the filter through the underdrainage system exceeds the accepted

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drinking water standards.[10] For the next step of the process, the authors wrote several proposals to various funding institutions presenting this project, and through these proposals, they further qualified the goal of their project: to provide clean drinking water to a community in the Mutale River Valley. The authors received funding from the University of Virginia Institute of Practical Ethics and from Davis Projects for Peace.

When the authors arrived in South Africa, the research cohort consisting of the authors and Univen students began its involvement in the village by conducting a site assessment using Institutional Review Board (IRB) approved household surveys[11] and water sample tests. Because of the inconsistent supply of municipality water, some of the villagers had installed pipes to carry water from a river in the mountains to their homes. Approximately fifty households had paid for these pipes from the mountains out of the five hundred households in the village. Surveys of 46 households throughout the community revealed that 83% of the heads of the households believed that their water was not safe to drink (Table I); this idea was validated by the water sample tests which indicated that the piped water was contaminated with microorganisms, including *E. coli* and salmonella (Table II). Many households also reported that bilharzia (schistosomiasis) and other water-borne diseases were common.

TABLE I
HOUSEHOLD SURVEY RESULTS FROM FIRST COMMUNITY

Survey question	Summary of Responses
Average household size	5.2
Overall water use	240 L/day
Water used for drinking	28 L/day
Frequency of water from municipality	Once every 3 weeks
Alternative water sources used	28% from pipes in mountain, 60% from river, 9% from boreholes
Safety of alternative sources	83% believe water is not safe to drink
Use of boiling water	27% boil water
Use of bleach disinfection	9% use bleach

TABLE II
WATER SAMPLE RESULTS FROM FIRST COMMUNITY

Sample*	Borehole	Pipes from mountain	Tshala River	Irrigation stream	Underground spring
HPC	31†	15†	Confluent	17†	30
mEndo	NG (no growth)	3	1	NG	NG
m-FC	NG	NG	30†	NG	NG
TCBS	NG	NG	NG	NG	NG
MCA	18	10	604	1	NLF (non-lactose fermenting)
BGA	NG	59	444	12	NG

* HPC = Heterotrophic plate count, mEndo = total coliform, m-FC = fecal coliform, TCBS = Vibrio selective agar, MCA = MacConkey Agar (enterobacteria), BGA = Brilliant Green Agar (salmonella); † Average of two plates

In the next step of the process, the cohort held a community meeting where the U.Va. students and GSC students were introduced by coauthor Elias Ramarumo, a member of the community and Monitoring and Evaluation Officer for Centre for Positive Care, a local non-profit NGO. Elias explained the history of the collaboration between the universities and the community through the SAVANA consortium, and he also served as a translator during the presentation. The U.VA. and GSC students explained the results of the household surveys and water testing and proposed a purification system using slow sand filters as a potential solution. The filters would collect water from the existing pipes leading from the mountains to the community. The system would then purify and store this water in a central location to provide access to clean drinking water for all community members. Although the community approved this idea at the presentation, the researchers later learned that the water committee responsible for the pipes wanted the system to benefit only the fraction of community members who paid for their installation. The water committee's stance was inconsistent with a primary goal of the project: to provide sustainable access to clean drinking water for the entire community. Installing separate pipes for the entire community to use would cost thousands of dollars and take many weeks; therefore, limited time and resources prevented the cohort from arriving at a feasible alternative in this village and led them to relocate their efforts to a neighboring community. In an attempt to provide the initial village with direct benefits from the interaction, the cohort provided the community with verbal and written results of the household surveys and the water sample tests; they also compiled a pamphlet outlining proper purification methods using bleach or boiling as a substitute for slow sand filtration. These documents were presented both in English and in the local language, Tshivenda.

Both villages used the same source water from the mountains; however, a vast majority of the community members in the second village had paid for instillation of the pipes from the mountain river to their community. In addition, the second community had a pre-existing water storage system to aid in the distribution of water to the households. The water storage system was located on the chief's kraal, a well-protected and respected area monitored closely by a community operator, who was responsible for turning the main water valves on and off. This constant interaction provided the ideal setting for the introduction of a new filtration system. In the proposed plan, the researchers would construct two slow sand filters and integrate them into the existing network prior to the storage system so that the households would have access to purified water (Figure 2).

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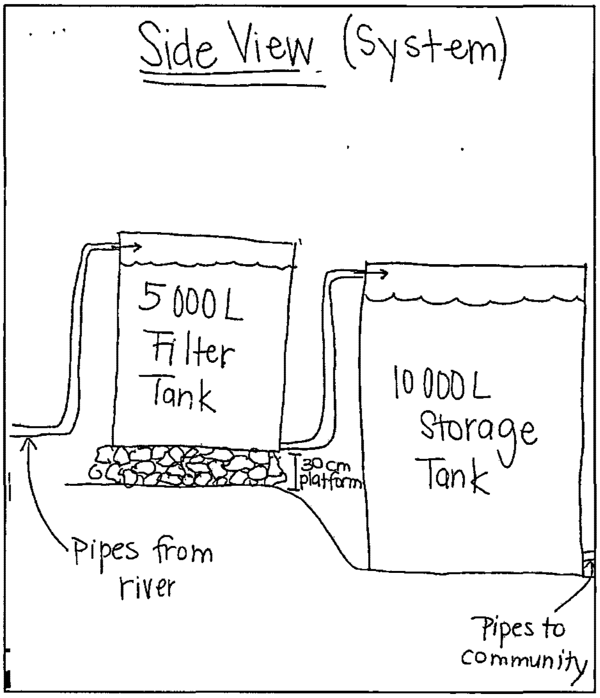

FIGURE 2
ILLUSTRATION OF THE PLACEMENT OF THE FILTERS IN THE COMMUNITY.

At the opening community presentation in the second village (Figure 3), the researchers learned that only two of the three major pipes passed through the main storage system. Due to limited time and resources, the cohort was able to complete only two filters, one for each of the main storage tanks in the system, leaving the water in the third pipe unfiltered. Instead of debating ownership of the pipes, the community members agreed that they would rather have partial access to clean drinking water than no access at all, and the households with a constant supply of purified water volunteered to provide the remaining households with a sufficient supply of drinking water. These households would use their existing unpurified water for cleaning, washing, gardening, and other activities. After the presentation, ten community members signed up as volunteers for construction and maintenance of the system.

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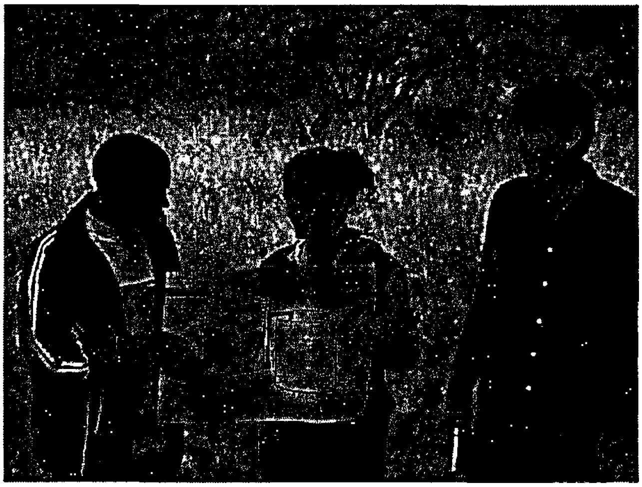

FIGURE 3
AUTHORS DELIVER A COMMUNITY PRESENTATION WITH TRANSLATION FROM DUNCAN NENGWENANI, A GLOBAL SUSTAINABILITY CLUB STUDENT.

The construction process for the slow sand filtration system took approximately four days and involved the ten community volunteers and the research cohort. The largest obstacle in the construction process was obtaining appropriately sized fittings for the system from the local hardware stores, and the most time consuming aspect of the process was transporting sand from the sand-pile to the filters (Figure 4).

FIGURE 4
AUTHOR AND COMMUNITY MEMBERS CARRY SAND TO THE FILTRATION TANKS.

At the final presentation following construction of the filters, the cohort explained the project and findings to the community members. They also provided a photo album of the project and a manual detailing the construction process, troubleshooting, and maintenance to both villages. Figure 5 shows the stakeholders in front of the completed filters. In addition, the Univen students later distributed certificates of appreciation acknowledging the efforts of the community volunteers.

FIGURE 5
AUTHORS, COMMUNITY MEMBERS, AND GLOBAL SUSTAINABILITY CLUB STUDENTS DUNCAN NENGWENANI AND SHADRACK NKOSINATHI IN FRONT OF SLOW SAND FILTRATION TANKS.

In addition to collaborating on the water purification project, the authors helped strengthen the rapidly-growing GSC at Univen. The authors offered advice and encouragement based on their experience with similar clubs at U.Va, such as Engineering Students without Borders and the Global Development Organization, thereby strengthening the connection between the two universities and enabling both sides to understand their shared vision for the future. The GSC has recently expanded their outreach to include volunteering at secondary schools in South Africa to teach youth about issues such as community development, water purification, environmental sustainability, and global warming. They also visit an orphanage in Thohoyandou where they play with the kids and donate clothes.

After the U.Va. authors left the community, the GSC continued to engage in the community and conducted water sample tests to assess the effectiveness of the slow sand filters (Table III).

TABLE III
WATER SAMPLE RESULTS FROM DECEMBER 2008 IN SECOND COMMUNITY

Sample*	Mountain stream		Filter tank 1		Filter tank 2		Storage tank 1		Storage tank 2	
	24 hrs	48 hrs	24 hrs	48 hrs	24 hrs	48 hrs	24 hrs	48 hrs	24 hrs	48 hrs
MCA	2	2	2	3	8	4	4	5	2	4
SSA	0	0	0	1	0	0	-	-	1	-
HPC	7	8	0	7	-	-	2	8	-	-
EMB	1	1	1	2	3	5	3	3	1	5
m-FC	1	1	2	3	15	10	18	15	1	1
m-Azide	0	0	0	0	0	0	0	0	0	0

* MCA = MacConkey Agar, SSA = Salmonella Shigella Agar, HPC = Heterotrophic plate count, EMB = Eosin Methylene Blue Agar, m-FC = fecal coliform, m-Azide = m-Enterococcus Agar; (-) represent results that were either unreadable or damaged.

The fields with dashes represent unreadable or damaged results, so an additional round of water sample tests are necessary to validate the data. Because the storage tanks were not cleaned prior to introduction of the filters, the unusually high counts in the first storage tank indicate the possibility of a pre-existing contaminant in the tank. Also, the GSC students noted that the water levels in the slow sand filters were quite low, barely covering the surface of the sand. According to Huisman and Wood,[12] authors of the World Health Organization's Slow Sand Filtration manual, these filters function most effectively under constant water flow rates, with seasonal fluctuations being the hardest deviations to handle. In the Mutale River Valley, the dry season corresponds with summer (December to March), which is when the water sample tests presented in Table III were completed. One possible cause of the low water levels in the filtration tanks is a lower water level in the source river in the mountains. The decreased water levels in the tanks could have damaged the biological layer at the surface of the sand that is responsible for breaking down the microorganisms in the river water. This damage would render the filters ineffective and could account for the contamination levels found in the water sample tests. Because the filters were improperly functioning, the community elected to turn valves that would bypass the filters and revert to their previously existing system for the duration of the dry season. At the end of the dry season the community began using the filters again, and the GSC students plan to return to the community to perform an additional round of water sample tests to verify the effectiveness of the filters. A follow-up group of U.Va. students will collaborate with GSC students this summer to assess the existing filtration system, explore potential water purification methods to be used during the dry season, and address the issue of the unpurified drinking water delivered to portions of the community through the third pipe that bypasses the storage system.

ETHICAL ISSUES

Throughout the duration of the community-based participatory research project, a number of ethical issues arose. The authors learned some lessons from this experience that can inform future student-led development projects. First, researchers in student-led projects typically have preconceived notions about what they want to accomplish in a particular community. These notions are necessary because proposals for university funding require the development of a specific project idea. In this project, the authors designed a slow sand filtration system prior to their arrival in South Africa. To select this approach, they employed a rigorous evaluation procedure including significant correspondence between U.Va. and Univen, and as a result, the authors were biased towards the selection of this technology over other options once they arrived on site. During the initial community presentations, the authors presented the results of the household surveys and water testing and suggested that a purification system should be built. Naturally, they recommended slow sand filtration although many other useful water purification systems exist. Examples of these technologies include solar disinfection, solar distillation (SODIS), and ceramic pot filtration. Since students implementing a project during the summer have only a couple months, they cannot feasibly discuss all of the possible options with the community and spend several weeks or months selecting the most appropriate one. After much debating the community approved the technology, but the actual design was much different than originally anticipated by the authors prior to arrival because of factors such as the water flow rate, the demand, and the environment.

In addition, the relationship between nearby communities caused an ethical concern. After the authors left the first community due to the communication issues and arguments over payment of the pipes, they presented the project in the second community located nearby and explained what had previously happened. They felt it was important to maintain transparency and eliminate misconceptions about why they left the first community. Unexpectedly, this approach caused a rivalry between the communities that almost prevented the project from taking place. The researchers had frequent communication with advisors at U.Va. and Univen throughout the project and did not expect to encounter this problem. Under the given constraints, the best approach may have been to enter the second community without a preconceived idea of constructing a sand filter and without mentioning the shortcomings of the nearby community. In projects such as this one, researchers may encounter significant cultural differences that they are not aware of despite their precautions to remain culturally sensitive.

Additionally, there was an issue over compensating the community volunteers for their work. Because the project was going to benefit everyone in the community, there was an explicit understanding that the volunteers would not be paid. Ten community members signed up and put forth great effort in constructing the sand filtration systems. As a sign of gratitude, the researchers brought lunch and cold drinks each day for the volunteers. Nevertheless, the volunteers repeatedly asked for payment for their labor. A gatekeeper in the community was persistent about providing benefits for the volunteers, and the authors were worried that the project could be derailed; however, through extensive dialogue this obstacle was overcome. In retrospect, the food that the researchers provided may have suggested that the researchers would be able to provide financial compensation to the volunteers, and perhaps the certificates of appreciation would have been sufficient.

PROJECT EVALUATION

George & Shams[13] discuss three simple questions to evaluate the effectiveness of service-learning projects: 1) Have the customers' needs been met? 2) Is the project sustainable and maintainable by the customer? 3) Does the project respect the environment and make effective use of local renewable resources? (p. 68). The authors applied these criteria to this project to determine its long-term impact. In this case the customer was defined as the community where the project was implemented.

1. Have the customers' needs been met?

The needs of the community, as defined by the cohort, were to obtain sustainable access to clean drinking water for each household. Sustainable meant that a system that provided potable water would use local resources, would be affordable, and would be maintained by the community members. Although household surveys were used to determine if these were reasonable objectives, the community members did not have input into the design of the survey and did not have an opportunity to suggest other objectives. Therefore, customer satisfaction at the completion of the implementation phase of the project was difficult to monitor, especially since the U.Va. authors then had to leave the community. Although the community bypassed the filters during the dry season because the pipes were not supplying a sufficient quantity of water, they turned the filters back on once the water levels were restored. Through their actions, the community members indicated a desire to maintain the system. Further water testing is needed to determine if the filters are now working properly; a follow-up group of U.Va. students will return this summer to evaluate the project and continue the collaboration with the GSC and the community.

2. Is the project sustainable and maintainable by the customer?

After the GSC students reported their water testing results when they attended the January Term course at U.Va. in January 2008, the authors determined that the slow sand filters were no longer properly purifying the water as expected. These tests were conducted around the same time that the dry season started, so it is possible that the water levels had dropped below the surface of the sand and temporarily deactivated the biological layer, or that the storage tanks contained fecal coliform residue that re-contaminated the water after it passed through the filters. During the dry season, the community turned a valve to allow the water to bypass the filters and continue directly to the storage tanks. The authors did not anticipate from their site assessment and conversations with community members that the water levels in the mountains would decrease enough during the dry season to prevent the supply of water to the tanks. If the community develops alternative methods of water purification when these conditions recur, the project could be deemed sustainable. However, until alternative methods are properly established and water testing demonstrates that the filters reliably purify the water, the project is not fully sustainable.

3. Does the project respect the environment and make effective use of local renewable resources?

By integrating the sand filters into the existing storage system, the project caused minimal environmental impact in the community. Apart from scraping off the top of the biological layer every six months and then allowing it to reform, the community did not have any additional work to maintain the system. All of the materials for the project, including the tanks, sand, gravel, PVC pipes, mesh fabric, and valves were obtained from local hardware stores in Venda, effectively using available resources.

Although the project respected the environment, used local resources, and mostly met the needs of the community, the filters did not supply a reliable quantity of water throughout the year so the project is not yet fully sustainable. However, coauthor Elias Ramarumo, a member of the first community, noted that the filters are generally working well and the community is satisfied. Although problems with the water supply have occurred at times, the community members still consider the project a valuable asset. Education about water issues is very important so that the community members understand that the filters may not be working properly even when they supply a proper quantity of water. This is one of the important responsibilities of the follow-up team.

Furthermore, Elias noted that one of the most important regional goals for the future is to develop communities so that everyone has access to clean drinking water, reliable health information, employment opportunities, and better roads. The government should help improve the water supply that they provided and community members should be more involved in making decisions that concern them. Duplication of services by different organizations should also be avoided by increasing collaboration between initiatives.

REFLECTIONS

The authors extensively prepared for this project both before and throughout the academic year prior to its implementation. The preparatory steps involved intense cross-cultural engagement, coursework concerning technical engineering and non-technical social aspects of such projects, and mentoring from advisors and from students that had already completed such projects. The authors also collaborated with their Univen partners on a regular basis, encouraging the exchange of information; they researched water purification methods, wrote multiple proposals, and obtained U.Va.'s IRB approval for their household surveys.

Despite this preparation, some aspects of the project did not go according to plans, and the authors were not able to anticipate the ethical concerns that developed. An essential but oftentimes ignored step in the planning stages of a cross-cultural community engagement project should be an initial site assessment. The authors did not complete this step until they already had a solution in mind, but in retrospect, a site assessment including household surveys could have greatly benefited the authors. First of all, the authors would have engaged the community prior to selecting a water purification method; as a result, the two groups could have truly collaborated to create a sustainable solution to meet the community's needs. In addition, the authors would have had the opportunity to perform an additional set of water sample tests at a different time of year to gain a better understanding of the seasonal impact on the quality and quantity of water resources. Finally, a site assessment could have exposed the conflict concerning ownership of the pipes in the first community. Uncovering this issue during a site assessment would have provided the cohort and community members with ample time to possibly alleviate this disagreement, and ultimately, the stakeholders may have been able to design a viable solution to address the community's water quality concerns. In general, undergraduate students tend to bypass site assessments because of limited funding or because of limited time. These students fund a majority of their projects using limited grant money, and because of the relatively short timeline of the projects, travel costs to an international destination make up a sizeable portion of a student's budget and limits the feasibility of an initial site assessment during the design stages of a project.

The short timeframe within which students plan to implement projects, typically only a portion of a three month summer vacation, can impact the outcome of such projects. Even without an initial site assessment, a longer time frame could have allowed the cohort to work through the conflicts in the first community. Had the cohort still shifted its efforts to the second community, the group would have had the opportunity to complete a second round of household surveys to improve communication and better gauge the community's water needs and perceptions. Also, the authors could have held educational workshops on water issues in both communities to increase understanding of topics such as the water cycle and transmission of water borne disease. Finally, had the authors allowed for more time after construction of the slow sand filters, which require a period of approximately two weeks to form the biological layer largely responsible for the filter's purification capabilities[14], they would have had the opportunity to complete an additional set of water sample tests to determine if the filters were working efficiently. If they were not properly purifying the water, the authors could have worked with the community members to trouble shoot the system.

In general, working within existing networks can help alleviate the issues concerning site assessments and time constraints. Partnerships with a community and a local university can establish long-term relationships that provide mutual benefits. Rather than using the community as research subjects, they are treated as partners in an exchange of knowledge and resources. The research of the SAVANA consortium in southern Africa, the framework from which this project arose, is an excellent example of institutional partnerships with communities.[15] Because the water purification system did not meet all of the project evaluation criteria for a fully sustainable project, another group of students will return to the region this summer to re-assess the community's water needs and the status of the filtration system. They will continue to collaborate with the GSC and the community to determine the most appropriate next steps in the process.

ACKNOWLEDGMENT

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Service-Learning at SEAS: Analysis of Existing Opportunities and Recommendations for Improvement

A Research Paper
in STS 402

Presented to

The Faculty of the
School of Engineering and Applied Science
University of Virginia

In Partial Fulfillment

Of the Requirements for the Degree

Bachelor of Science in Chemical Engineering

By

Eric Harshfield

April 30, 2009

On my honor as a University student, on this assignment I have neither given nor received unauthorized aid as defined by the Honor Guidelines for Papers in STS courses.

Signed ______________________________

Approved ______________________________ Date 5-10-09
Bryan Pfaffenberger, STS Advisor

Abstract

Service-learning provides a unique opportunity for students to integrate their academic coursework with meaningful service projects in collaboration with community partners and faculty advisors. A reflection component encourages students to transform their way of thinking and pursue further community engagement. Service-learning also enables cross-cultural experiences that challenge the traditional customs and values of the students. While the School of Engineering and Applied Science at the University of Virginia provides numerous opportunities for technical research, the mutual interaction of science, technology, and society requires that engineers think broadly about their potential impact on the world. Service-learning provides students with the resources and practical experiences they need to become leaders and improve the lives of the communities they serve. There are current limitations in the service-learning opportunities available for engineering students, but changes can be made with the input of students, faculty, administrators, and partner organizations so that programs provide mutual benefits to all stakeholders and ensure that service-learning projects have sustainable outcomes.

Approximately 1.1 billion people worldwide do not have access to clean drinking water and 2.6 billion people lack basic sanitation (Watkins, 2006). Community-based participatory research is an effective means to address these needs in developing countries (see, for example, Dayal, van Wijk, & Mukherjee, 2000; Mukherjee & van Wijk, 2002; UNHCR, 2008). Recently, service-learning as part of an undergraduate education has begun to allow students an opportunity to learn about and face these challenges (Mehta & Sukumaran, 2007; Newman, 2008). There are many benefits on both the individual student level and the institutional level to including service-learning as part of the undergraduate engineering curriculum.

Through involvement in service-learning projects, students move from theoretical knowledge studied in the classroom to real-world problems with numerous applications (Paquin, 2006). These opportunities prepare students for the design challenges they may face by teaching them about the social, cultural, and ethical issues in addition to the technical aspects. As global problems continue to escalate, integrated service-learning programs offer part of the solution by helping students develop important leadership skills and by increasing student commitment to community engagement after college (Paquin, 2006).

Institutionally, service-learning programs help align the engineering curriculum with the Accreditation Board for Engineering and Technology's (ABET) Engineering Criteria 2000 (EC 2000), which states that students should attain "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (ABET, 2008). Promotion of service-learning also increases research opportunities for the institution and improves its ability to form partnerships and exchanges. Partnerships with community organizations and other institutions increase the competitiveness of funding proposals and the domestic and international competitiveness of the institution. Additionally, service-learning helps improve the retention and success of minorities and women, who are outnumbered in most engineering disciplines, by engaging diverse groups of students in projects that serve humanity (Paquin, 2006).

There are several limitations to implementing service-learning programs in the School of Engineering and Applied Science (SEAS) at the University of Virginia (U.Va.). This paper addresses the question what steps should be taken to improve the opportunities for engineering students to conduct effective service-learning projects? Recommendations will provide opportunities for SEAS to address three core challenges: lack of institutional support, failure to meet ethical concerns, and high risk of project failure.

Lack of Institutional Support

Engineering students at U.Va. have a strong desire to make a difference in the world. In the last three years, over forty engineering students have conducted research projects in places that include South Africa, Cameroon, Uganda, Belize, Guatemala, Honduras, Mexico, India, and of course Virginia. In spring 2009, Engineering Students Without Borders (ESWB) cosponsored a Social Entrepreneurship & International Development conference with approximately four hundred students in attendance. The symposium at the conference had over twenty poster displays of ongoing student research projects. Additionally, through the student-led initiatives in ESWB, more experienced students have served as mentors for future groups of students to plan projects. However, these individual student efforts are insufficient without institutional support. Two important areas for improvement are providing support from faculty and administrators and better preparing students by integrating service-learning into the engineering curriculum.

Providing Faculty and Administrator Support

Support from administrators is essential for the development and sustenance of service-learning programs. The current policy of retention, promotion, and tenure rewards faculty based on research, teaching, and service, with research noticeably the primary area of focus at U.Va. Faculty are thus strongly encouraged to pursue publications that will yield funding for the university. Unfortunately, this makes it difficult for faculty to spend enough time focusing on the needs of students who follow non-traditional engineering paths such as service-learning. Realistically the need for funding is very important and the incentives system is unlikely to change in the near future; however, attitudes toward service-learning and the definitions of what constitute research and teaching can and should change. SEAS Dean James Aylor said, "I think the best think you [as a student] could do is to figure out a way that the project that you're working on is somehow consistent with what [a faculty member is] trying to do in the research. So that when you work with [the faculty member] on this project, then [they are] going to get a paper out of it. It doesn't have to be the most prestigious technical journal, but it could be some student journal or something like that. So I think you've got to incentivize the faculty around things that they really get credit for, unfortunately" (personal communication, April 15, 2009). Edward Berger, SEAS Associate Dean for Undergraduate Programs, agreed, saying, "I view the service-learning stuff as not at all exclusive from research, because you could do lots of good research actually within the project. There's lots of good research going on about how to do good service-learning.... [But] it takes a little work to do. It's not as easy as just writing a proposal to NSF and getting money from them.... And that's another barrier too is that I think faculty who have an interest... don't know quite how to start and how to get into it in such a way that it is consistent with whatever research they're doing" (personal communication, April 10, 2009).

Service-learning is distinguished from "service" in that it builds community partnerships through scholarly and instructional activities rather than simple volunteering in a community (Duffy, Tsang, & Lord, 2000). Robert Swap, Research Associate Professor in the Department of Environmental Sciences, said, "I think one of the biggest barriers is we keep talking about service, service, service, and we're not talking about the learning outcomes that come with it" (personal communication, April 10, 2009). The administration needs to recognize the value of service-learning and clearly relate this to the faculty. U.Va. should establish formal partnerships with other institutions and community organizations, enabling faculty involvement in collaborative research that will attract funding. Furthermore, engineering students should conduct research projects that plug into new and existing partnerships, strengthening relationships and allowing numerous opportunities for creativity and development. This will enrich the educational experience of the students while simultaneously increasing the prestige and quality of the research in which the university engages. Dean Aylor took a more negative outlook, saying, "Well, unfortunately right now there [is] not any [preparation for student service-learning projects]... it's not a good infrastructure in place to guarantee this is going to happen. I think there are people, like [Robert] Swap, putting things together to help people go. I don't know what the status of [the Engineering and Community Engagement] program is.... I haven't kept up with that, but unfortunately with the budget cuts and stuff like that, I'm not able to just really dedicate somebody to do it. Most of the efforts like that are done on top of what everybody else is doing. Unfortunately there's not enough behind this to make it happen" (personal communication, April 15, 2009).

Another related problem is that there are not enough SEAS faculty who are currently pursuing service-learning or have expertise in this area. This makes it difficult for students to find helpful advisors for their projects. However, as the university continues to push towards more service-learning programs, faculty will begin experimenting with these initiatives in their courses and the curriculum will gradually develop. Edward Berger said, "What it really takes is a champion to just do it.... We would love to just clear people's schedules off a little bit so that they would have time to devote to this, but it's hard" (personal communication, April 10, 2009). The Engineering & Community Engagement program handbook summarized the service-learning programs from other engineering schools, such as Duke University, MIT, and Purdue University, so that U.Va. can develop a similar model (Kirkpatrick & Yamakoshi, 2008).

Improving Student Curriculum

Duffy et al. (2008) described an immensely successful engineering program at UML where service-learning has been integrated into the curriculum as part of the core required courses in each discipline. The current SEAS curriculum does not provide students with the necessary skills to work with communities to effectively address their needs and to understand the underlying social, cultural, and ethical issues of community development. SEAS has a limited number of courses that provide students with service-learning opportunities or that even address global development. CE 330 Water for the World exposes students to many water and sanitation concerns facing communities worldwide. Likewise, the Department of Science, Technology, and Society, through a series of three required courses and one elective course, aims to encourage students to develop their communication skills and their understanding of the "interactions between technological change, science, and society... to use technology for advancing human welfare" (Department of Science, Technology, and Society, 2007). These courses, despite exposing students to important global issues, do not specifically prepare students for service-learning; however, there are a few courses that do address these issues more directly. SEAS participation in the national organization Engineering Programs in Community Settings (EPICS) allows first-year engineering students take ENGR 162 Intro to Engineering, enabling them to use an engineering approach to execute local service-learning projects. The Engineering in Context (EIC) program also allows students to design and implement a project in a community, but the project phase only takes place in the fourth year, which is late for students who may consider a career in a development-related field. A new course, ENGR 295 Engineering in Community Settings, offers the training, research, and experience that students truly need, but limited funding may prevent this course from being available in the future. Cara Magoon (CE '10), who took the class last fall, said, "[It] prepared me to think of the little things and really analyze everything that I do for ethical implications and long-term effects" (personal interview, April 10, 2009).

Additionally, the January term course offered by Professor Robert Swap, "Ethics, Protocols, and Practices of International Research," pairs U.Va. students with southern African colleagues to learn about issues in international research and write proposals for development projects. The summer study abroad course that Professor Swap also offers, "People, Culture, and Environment of Southern Africa," allows students firsthand interaction with the communities that they learn about to understand "the complexity of coupled human-natural systems of southern Africa" (Swap, Walther, & Annegarn, 2008). Engineering students should not be forced to take January term and summer courses as one of the few available means to learn about the cultural and ethical issues of service-learning, but the curriculum currently offers few other choices. Edward Berger said, "I think from the curricular side, the engineering curriculum itself... isn't really accommodating enough to allow some of these things to happen during the semester. Which forces them to happen over the summer. Totally ok, but lots of students don't want to do it over the summer. They want to get a job and make money. So there's something there that I think we could do better. That's a really hard thing to get the curriculum to be more open to this sort of stuff" (personal communication, April 10, 2009).

While the courses mentioned are excellent and deserve recognition, they are insufficient to prepare students to carry out extensive service-learning projects, especially if they travel abroad. Moreover, only a small percentage of engineering students are actually able to take them. Additional courses that could be offered include Global Public Health in Engineering, Business and Social Entrepreneurship in Engineering, Economics and Ethics of Sustainable Development for Engineers, and Environmental

Policy and Resource Management for Engineers. Furthermore, language courses geared towards engineers should be offered. Engineers have immense difficulty enrolling in the Spanish courses in the College of Arts & Sciences, and courses in other languages such as French, Portuguese, Arabic, Chinese, and Swahili are not available to engineers unless they pursue a minor (Kirkpatrick & Yamakoshi, 2008). Cara Magoon said, "I don't feel prepared in language.... That was the biggest letdown of the engineering school. Not being able to take a language and be proficient in it and be able to use that in international setting. We're all about engineering globally, but then you can't take languages.... I tried for years to get into Spanish and they would not let me in" (personal communication, April 10, 2009).

The stringent requirements for the undergraduate engineering degree leaves little space in the curriculum for engineers to pursue courses in sociology, anthropology, history, and other disciplines. This often leads students to perceive a "technical fix" to a community problem, focusing solely on a technical solution while ignoring the social and ethical implications of their work (Pacey, 1983). Students need opportunities to take cross-disciplinary courses and work on interdisciplinary teams to learn the necessary skills for conducting effective service-learning projects. Engineers are not typically provided with the training to understand what constitutes an "appropriate technology" and how to contribute to social change, essential components of service-learning projects (George & Shams, 2007). New paradigms for engineering education are needed to "accommodate a far more holistic approach to addressing social needs and priorities, linking social, economic, environmental, legal, and political considerations with technological design and innovation, and...to reflect in its diversity, quality, and rigor the characteristics necessary to serve a 21st-century nation and world" (Duderstadt, 2008).

Failure to Meet Ethical Concerns

Increasing the opportunities for service-learning likewise requires increasing attention to ethics. A human rights-based approach can help illuminate some of these concerns. This approach seeks to increase human development by strengthening capacities through empowerment and accountability. The United Nations Development Programme (UNDP) summarizes the major principles of this approach using the acronym PANEL, which stands for Participation, Accountability, Non-discrimination, Empowerment, and Linkages to human rights standards. The UNDP has also developed training resources and programs to promote a rights-based approach to development (Tomas, 2005). Besides the right to health, it is noteworthy that the Universal Declaration of Human Rights includes rights derived from inherent human dignity. "By extending human rights beyond the narrowness of consent or custom, this allows for recognition of a variety of nonstate actors as human rights violators" (Offenheiser & Holcombe, 2003).

Students should use a human rights-based approach to service-learning projects while also meeting other ethical concerns. Two key areas of focus are ensuring that projects are sustainable and appropriately balancing priorities between different stakeholders.

Ensuring Sustainability

According to Visscher (2006), past director of the IRC International Water and Sanitation Centre, a project is sustainable when it "a) continuously provides an efficient and reliable service at a level which is desired; b) can be financed or co-financed by the users with limited but feasible external support and technical assistance; and c) is used in an efficient way, without negatively affecting the environment." These are reasonable minimum standards for community development projects; however, most of the past engineering projects at U.Va. have been unable to meet these standards. For example, in the Limpopo Province of South Africa, U.Va. students have worked with local University of Venda students and community members on biogas digesters, solar lighting, solar disinfection (SODIS), water filtration using moringa seeds, rainwater harvesting, and small-scale slow sand filtration at a pre-school. All of the projects, except for the solar panels, did not work properly or were abandoned by the community after the students left; these projects could not be called "sustainable" by Visscher's criteria. The slow sand filtration system implemented by the author in the same region during the summer of 2008 also faced challenges, but a group of students is returning to follow up on this project. Although most projects did not turn out as planned, the students still learned valuable skills in conducting a project, working with community partners, and reflecting on their experience in the form of papers and presentations.

Another important aspect of sustainability is providing the community with the necessary skills and resources to maintain the project. Parsons (1996) noted, "Without the empowerment of local people, engineering projects in developing countries are doomed to fail. Engineers must learn to listen to local populations, working within the social, environmental, and economic context of their projects."

The short time frame available for students to conduct projects is also an obstacle. Students typically only spend a portion of a three-month summer vacation carrying out a project, while building relationships and planning with communities requires an extensive amount of time. Students must establish and maintain these dialogues before they and their partners can implement a sustainable system in the community. Since the academic calendar is a challenge and the community will always be on a different time frame, students and faculty should sustain ongoing relationships and ensure that they are culturally attuned to the needs of the community.

Additionally, rather than treating the community as research subjects, community members should be treated as partners in the reciprocal exchange of knowledge and resources. The community should be equally involved in the decision-making process so that projects will make long-term impacts.

Setting Priorities

Since there are many different stakeholders involved in service-learning projects, it is important that all voices are heard and that priorities are balanced. Students have a need to further their own education, to serve the communities they are working in, and to follow the requirements of the university. Institutions must balance priorities between the educational needs of students and the communities with whom they establish partnerships. Faculty must consider their multiple roles as researchers, educators, and servants. Different voices in the community, including women and children, also need outlets to communicate. Brooke Yamakoshi (CE '06, SE '07), said, "I think our projects succeeded in terms of meeting their educational goals—we, the students, learned more than we ever could have from three months in the field than from three years in the classroom" (personal communication, April 19, 2009).

There are numerous ethical and human rights issues that have to be balanced with educational and institutional goals to determine how to address the community needs most effectively. Communication, respect, and reciprocity are essential factors in making these decisions.

High Risk of Project Failure

Students tend to view the success of a project differently from faculty and administrators. The definition of success is important because it affects how different stakeholders view the project and how they actually implement it. Likewise, students often develop unrealistic expectations for what they hope to accomplish in a project, which can lead to inadequate follow up efforts.

Defining Success

Engineering students usually have a technical goal in mind when they develop a project idea, such as to build a water purification system or to install solar panels. If the device is not completed as planned or does not work effectively after they leave, the students often view the entire project as a failure. Visscher's sustainability criteria are one means of assessing the success of a project; however, faculty and administrators typically evaluate a project based on the learning outcomes achieved. If a student develops a relationship with a community and both parties learn something from the exchange, then the project could be deemed a success even if the project itself was abandoned. However, with so many abandoned projects in the past few years, it is important that students follow-up on these efforts to correct previous limitations and learn from past mistakes. The establishment of institutionally supported service-learning programs will be essential to follow a more ethical approach. Ricky Sahu (SE '09), who built a biodigester in South Africa, recognized this outlook. He described his project, "I think it was successful in engaging the community and exciting them about these kind of activities, and I guess basically helping the people around them with sustainability. I don't think it was successful in the technical aspect of the biodigester" (personal communication, April 10, 2009).

Robert Swap said, "To be successful, one big thing is planning. And I think one of the first things to do as I keep saying is to ask and having an informed question…. So you can't predetermine or preordain what's going to happen, you have to talk to people and get into dialogue. So what can you do before? You can understand what a community is, go out there and read a little bit about a rights-based approach, and do the kind of things we do in ENGR 295 and Development on the Ground, you allow yourself nine months to a year lead-time, saying, 'I would like to do something.' It doesn't mean you can't do stuff in between, but if [you] want to work internationally you need to allow [yourself] nine to twelve months to be able to do this" (personal communication, April 10, 2009). The preparation aspect, developing the right frame of mind and asking the right questions, is essential for any service-learning project whether conducted locally or abroad. For a successful project, all stakeholders must set reasonable expectations for what can be accomplished.

Setting Expectations

Faculty are only part of the reason why projects are product-oriented. For individual projects, students must write grant proposals to obtain funding for their research. Grants only provide one lump sum and do not usually enable students to conduct an earlier site assessment, which would permit them to evaluate the community needs and work with the stakeholders to brainstorm solutions instead of proposing their own solution to a problem that they do not fully understand. Proposals are typically selected based on a realistically conceived idea for a project that can be sustainably implemented. Projects that indicate students will take multiple trips to visit a community without a specific solution in mind seem too open-ended and do not usually receive funding, but this is precisely what proposals should state. The funding criteria need to be revised so that students can conduct projects that ethically meet the goals of service-learning.

In an ideal service-learning program, the research would take place in a community or a particular region where faculty have previously established contacts, and students would take multiple visits to better understand the needs of the communities and work collaboratively with them to develop a solution through their coursework. Faculty would have opportunities to publish their research and students would have unparalleled academic experiences.

Conclusions and Recommendations

The University of Virginia has started developing a priority to integrate civic engagement and academic learning through initiatives such as the Commission on the Future of the University, the Commission on Diversity and Equity, and the Virginia 2020 Public Service and Outreach Commission. Dean Aylor said, "There basically were three areas of emphasis in [the Commission on the Future of the University]. One was the student experience on Grounds. Second was international or globalization, and then [the] third was science and technology. So from a University standpoint, they're putting a fair amount of emphasis on [service-learning]. And there [are] some dollars behind it at the

University" (personal communication, April 15, 2009). Most recently, the Jefferson Public Citizens program (JPC) in the Office of the Provost enables students to conduct academic community engagement projects with a community partner and a faculty advisor. Megan Raymond, Director of Academic Community Engagement, said, "What I really hope is that [JPC] is a compliment to [other University programs], that it gives students the opportunity to work in teams, to work with students in other schools and other departments, to develop a project or plan a project that they may have been building on in a one-week Alternative Spring Break trip or part of a J-term class.... Through the JPC program the students envision a much longer-term engagement with that partner. Working on a project that's going to take a long time to either untangle, or solve, or produce some good results for that community partner. So I hope it's really an enhancement and it allows people to expand and sustain their local engagement that students may be getting through other activities" (personal interview, April 14, 2009).

U.Va. is beginning to recognize the value of service-learning in preparing students for effective leadership roles, improving the quality of institutional research, and meeting the important needs of developing communities. However, there are numerous challenges for students, communities, and institutions to overcome. To improve support from faculty and administrators, the incentives system should be changed to promote service-learning. While this will be quite challenging to accomplish, U.Va. is quite capable if it follows the model of numerous other universities. The SEAS curriculum will be difficult to modify so that students are better prepared for service-learning projects, but changes are already occurring and with continued efforts from students and faculty more resources will be available. To make projects more sustainable, faculty should establish long-term partnerships with other institutions and community organizations, allowing students to conduct individual projects as part of a larger academic program. Furthermore, reasonable expectations from students, faculty, administrators, and funding organizations will ensure that projects are carried out collaboratively and maintained by the communities. By identifying some of the limitations that SEAS needs to address and offering recommendations from both the literature and from interviews with students, faculty, and administrators, this paper will assist the engineering school in continuing to improve and expand the opportunities for service-learning.

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12/14/08
updated
prospectus
to AB

A Framework for Implementing Sustainable Water and Sanitation Systems in Rural Communities: Case Study of a Slow Sand Filter in Limpopo Province, South Africa

A Thesis Prospectus
in STS 401

Presented to

The Faculty of the
School of Engineering and Applied Science
University of Virginia

In Partial Fulfillment

Of the Requirements for the Degree

Bachelor of Science in Chemical Engineering

By

Eric Harshfield

December 14, 2008

On my honor as a University student, on this assignment I have neither given nor received unauthorized aid as defined by the Honor Guidelines for Papers in STS courses.

Signed ______________________

Approved K.A. Neeley ______________________ Date 12/17/08
Kathryn A. Neeley, STS Advisor

Approved ______________________ Date 04/24/09
Robert J. Swap, Technical Advisor

Water is an important resource and a basic human need that must be fulfilled to survive (Gleick, 1998a). People without access to clean drinking water commonly face malnutrition and numerous water-borne diseases. Sustainable water purification systems—easily maintained methods of providing clean drinking water—that are designed for rural communities are an effective means to reduce these problems. However, there are certain ethical issues that arise in community development projects (Flicker, Travers, Guta, McDonald, & Meagher, 2007), such as how to empower the community members to take charge of the project and maintain the system in a sustainable fashion. These procedures are used effectively by some individuals and organizations (Beard & Dasgupta, 2006; Mukherjee & van Wijk, 2002; Seifer, Shore, & Holmes, 2003), but since the problems arise from contextual factors that are unique to each situation, a general solution does not exist. The best practices for sustainable community development on water and sanitation projects have not been fully established.

This research will focus on the analysis of a water purification system that Ana Jemec and the author constructed in the Limpopo Province of South Africa during the summer of 2008 in collaboration with community volunteers, students and faculty from the local university, and other stakeholders. Professor Robert J. Swap will be the technical advisor for this project. He brings over fifteen years of experience with community development, particularly in Brazil and South Africa. This project will develop a framework to determine the best practices for the sustainable implementation of water purification systems in rural communities in developing parts of the world.

Problem Statement

As Josephine Ouedraogo (2005) said on World Water Day 2005, "Water is critical for sustainable development and indispensable for human health and well being." Water-borne diseases caused by contaminated drinking water are a significant problem in many parts of the world. Diarrhea and other hygiene-related diseases are responsible for about 2.2 million deaths each year (Thompson, Sobsey, & Bartram, 2003, p. S89). Bradshaw et al. (2004) also found that diarrheal diseases were the second-highest cause of premature mortality in the Limpopo Province of South Africa for both adults and infants. Additionally, the lack of access to clean water and the improper management of freshwater resources have affected human populations and led to the destruction of the environment (Gleick, 1998b).

The South African Constitution has guaranteed a right to water since 1996. Likewise, the Millennium Development Goals seek to "halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" (United Nations, 2008, p. 40). Water purification systems designed for rural communities can be effective to reduce these problems if they are implemented in a sustainable manner.

Researchers have taken many different approaches to address these needs. Beard and Dasgupta (2006) studied collective action and community-driven development in Indonesia, finding greater rates of success when the project facilitators engaged the community in identifying the important issues and participating in the solution. Other researchers (Mukherjee & van Wijk, 2002, p. iii) used the methodology for participatory assessment (MPA) to "empower poor communities to plan, manage, and sustain their water and sanitation services, and gain control over their life, health, and environment." Partnerships between a community and a local university can also establish long-term relationships that provide mutual benefits. Rather than using the community as research subjects, they are treated as partners in an exchange of knowledge and resources (Seifer et al., 2003). This type of relationship has been established through the South African and Virginia Networks and Associations (SAVANA) consortium, a network of researchers from the University of Virginia working with multiple universities and community partners in southern Africa (Swap, Annegarn, & Otter, 2002). While these initiatives and countless others have been successful, each situation has unique contextual factors that contribute to the problems. Therefore, a general solution does not exist and best practices need to be established to develop a better understanding of community development. The purpose of the thesis project described here is to develop a framework for the sustainable implementation of water purification systems in developing communities.

This project aims to:

- Assess the effectiveness and sustainability of the water purification system constructed in South Africa by Ana Jemec and the author.
- Evaluate the implementation and broader impact of community development projects focused on water purification and sanitation in rural communities.
- Develop a framework for the best practices of community development in this setting.

Approach

The water purification project developed in South Africa will be used as a case study for community development in rural areas. The researchers divided this work into five phases, consisting of 1) general research while at U.Va, studying the water problems in Venda and selecting the optimum design for a purification system; 2) preparation for the project at U.Va, constructing a prototype based on the specifications by the World Health Organization (Huisman & Wood, 1974), and developing household surveys; 3) detailed research upon arrival in South Africa, meeting with students and professors at the University of Venda for Science and Technology (UNIVEN), meeting with the chief of the village, and administering household surveys; 4) implementation of the system in the community (shown in Figure 1), constructing two sand filtration systems with assistance of ten community volunteers and UNIVEN students; and 5) follow-up steps, providing a manual that detailed the construction process, troubleshooting, and maintenance. Steps were taken to ensure that the system would be maintained by the community and that regular water testing by the UNIVEN students would monitor the effectiveness of the filters.

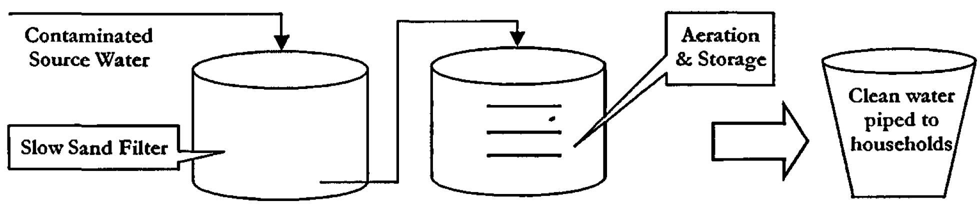

Figure 1: Diagram of slow sand filtration system [Created by Ana Jemec and author].

Comparison of other development projects that address water needs will provide useful metrics for establishing the best practices of community-based participatory research. After studying these projects and evaluating what worked and what did not from cultural, organizational, and technical perspectives using the "triangle of technology practice" (Pacey, 1983), a framework for conducting projects in this setting will be established.

Significance: Intellectual Merit

The project in South Africa was carried out with great sensitivity to the social, organizational, and technical issues involved in community development. While the project was not a perfect model of best practices for sustainable implementation, the lessons learned from this experience will provide a useful case study in the comparison and evaluation of other projects. The researchers built on over five years of collaboration between U.Va and UNIVEN through the SAVANA consortium (Swap et al., 2002), developed in part by the technical advisor for this thesis, which allowed smoother implementation of the project with logistical support from previously established contacts. Both researchers had the necessary academic skills from their chemical engineering coursework and relevant research experiences. The author had previously worked with the selected community in South Africa, and Ana Jemec had spent two summers working with an environmental firm to test wastewater, qualifications that contributed to the overall success of the project.

Significance: Broader Impact

The researchers collaborated with the stakeholders to develop a working water purification system that may help to alleviate the health risks associated with contaminated drinking water. Additionally, they shared the results of the household surveys and water testing with the community to allow all stakeholders to fully understand the problems. The detailed construction manual for the sand filters and the strongly established relationships will allow future development in the region. The Sustainability Club at UNIVEN will enable students to work on many additional projects addressing the needs of rural villages in South Africa. The researchers gave final presentations in the community and at UNIVEN; also, they have presented their research at several U.Va forums and anticipate publication in international service learning journals. The analysis of community development challenges in rural communities will be useful for anyone wishing to pursue this type of research.

Social and Ethical Issues

There are a number of important ethical issues to consider in this project. Participatory engagement was a necessary component of the interactions with the community. Community development workers should strive to empower the community to identify the issues they are facing in order to reach a viable solution. It is essential to follow proper IRB protocol by informing patients of the risks, but also to ensure transparency by keeping open lines of communication about the purpose of the study and the results obtained (Flicker et al., 2007).

While education about hygiene and safe water usage are important (Carter, Tyrrel, & Howsam, 1999), reciprocity is necessary so that both parties learn from each other (Singer et al., 2003). The community must learn from their interactions with the researchers how to identify their own needs and develop sustainable solutions, utilizing the knowledge and resources provided. The researchers must also share their results with the community to continue a long-term engagement. This mutual shaping of researchers and communities allows for effective grass-roots efforts to take place, decreasing the worldwide disparate levels of poverty and improving access to clean drinking water, sanitation, education, and affordable health care.

Conclusion

This research will help develop a framework that considers the ethical issues involved in community-based participatory research. A case study from the water purification project in South Africa will be compared with other types of community development projects to establish best practices for working with rural communities, particularly focused on meeting water and sanitation needs.

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