
AC 2011-2888: STUDY ABROAD IN GHANA AS A TOOL IN TASK IDENTIFICATION FOR BIOENGINEERING CAPSTONE DESIGN

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Study Abroad in Ghana as a Tool in Task Identification for Bioengineering Capstone Design

Abstract

Study abroad course-work presents unique collaboration potential with capstone engineering design, specifically as a source for student projects. Project-based instruction of bioengineering capstone design hinges upon engaging the students' interest and commitment early in the project. Strategies to achieve this level of student commitment can include encouraging student-originated project ideas, seeking projects from real-world external clients in research and industry, or offering instructor-originated projects orchestrated specifically to elicit student interest. Another alternative, soliciting student-originated engineering design projects derived from study abroad courses, allows for practical projects with real-world applicability and adds an element of the exotic to maintain student interest.

In the summer of 2010, two bioengineering students were sponsored to participate in a Syracuse University Study Abroad program titled "Healthcare for All: Sustainable Design for Healthcare Delivery in Ghana." The course, originated by the Syracuse University School of Architecture, focused on healthcare infrastructure for the developing world. In addition to the course objectives for that class, the two bioengineering students were tasked with identifying technical problems to be addressed in their bioengineering capstone design class the following semester. While in Ghana, the students were able to perform background research at teaching hospitals and rural clinics, and interacted with health professionals and policy makers including the Minister of Health. In the subsequent semester, both students initiated engineering design teams for their capstone projects, focusing upon the healthcare needs of the rural poor in developing nations. In addition to fostering task identification for relevant problems in Ghana, the experience abroad provided ample information for task clarification, informing project constraints. Specifically, the students developed projects on "Broadly Applicable Sterilization Techniques in Rural Clinics" and "On-site Production of Sterile IV Saline Solution for Treatment of Diarrhoeal Disease." Given the experience of the students who had been abroad, the teams were able to make informed assumptions about materials available, limitations to utilities and maintenance, and presence and training of healthcare personnel at the community level. This case study in collaboration between study abroad and capstone engineering courses suggests great potential in engaging student interest in projects, providing projects with real-world applicability, and facilitating task clarification through extensive background knowledge.

Introduction

Establishing novel design projects for Capstone Design courses can be extremely challenging. A core element of engineering design philosophy emphasized heavily in text books is that the first stages of the design process are task initiation and task clarification, sometimes referred to as needs finding and needs screening. Regardless of the terminology, success in these initial stages

has tremendous impact on the final deliverables of a project. Texts emphasize the need for substantial information gathering during task initiation, performing detailed background research, questioning underlying assumptions, and objectively observing the end user, use case, and environment which the project will serve. Once the problem or need has been clearly elucidated, only then is it wise to continue to the next step, often termed solution search, brainstorming, or ideation.^{1,2} In the context of a Capstone Design project, however, there are additional concerns in identifying a design problem, establishing the interest of the students being a primary one. Capstone Design is expected to encourage active problem solving, teamwork, and communication, for which student investment is required. One strategy to establish this interest is to investigate not just an individual client or patient's need, but a societal one. Hence the project elicits both the students' desire to solve the problem and the desire to make a difference. Projects intended to address needs in underdeveloped nations are particularly compelling in this regard. International design projects contain elements of cultural learning, cross-cultural communication and collaboration, and potentially greater societal impact.³ Further, such projects directly address the ABET requirement for providing engineering students with "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."⁴ This cultural experience is enhanced for students who are able to travel in the context of their design course, as students in an abroad program experience a measurable increase in cultural sensitivity.⁵

This paper presents a case study at Syracuse University in which a study abroad experience was used to identify societal healthcare needs in a developing nation and establish design projects based upon those needs for a Bioengineering Capstone Design course the following semester. In premise, this program is similar to the successful Beyond Traditional Borders program of Rice University, in which a large, multi-disciplinary design class develops projects to address societal needs in developing nations, and, afterwards, smaller numbers of student interns are sent abroad to implement those projects.⁶ The order in the Syracuse University program is reversed with the abroad portion occurring first and having a greater focus on task initiation and clarification. Both programs provide compelling design projects with global applicability, both allow direct cultural study by the individuals going abroad, and both are, in principle, cost effective, where the travel of a single student can enrich the experience of a larger class.

In the summer of 2010, two bioengineering students, rising seniors, enrolled in the Syracuse University Abroad/School of Architecture course, "Health for All: Sustainable Design for Healthcare Delivery in Ghana." They participated in all aspects of the Health for All course while also conducting interviews and performing background research with the goal of identifying and clarifying a task for a Capstone Design team the following semester. In addition to giving these two students a cross-cultural experience, this collaboration allowed for two full design teams of students to share in the experience later, designing products with global applicability. The two students who participated in the summer course were able to supplement

the design teams' research with extensive personal knowledge of environmental, material, and cultural constraints to the design problems, thus improving the quality of the final deliverables.

Abroad Component

Health for All is an interdisciplinary Syracuse University Study Abroad and School of Architecture course held in the summer of 2010, attracting students with majors ranging from Engineering to Anthropology. The course, instructed by Yutaka Sho and Kevin Lair of Syracuse University School of Architecture and Rebecca Bollin of St. Joseph's Hospital, focused on the complexity of designing healthcare infrastructure for an environment where availability of utilities, cultural differences, and regional health concerns generate obstacles to conventional western medical programs. The course consisted of five weeks spent in Ghana. During their stay, students visited numerous village clinics, several area hospitals, the School of Medicine in Tamale, Ghana Health Services, and the Ghana Ministry of Health. A map of the travel throughout Ghana can be seen in Figure 1 below. Students arrived in the capital of Accra, made a day visit to St. Francis Xavier Hospital in Assin Fosu, flew to Tamale, the largest city in the more rural north, and subsequently traveled to the village of Navrongo and city of Kumasi.

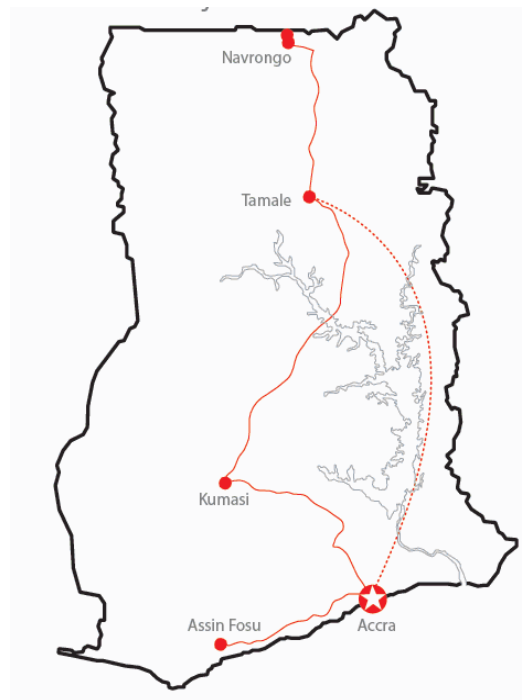


Figure 1: The travel map for the abroad component

Throughout, the students were introduced to aspects of healthcare particularly relevant in Ghana, including endemic illnesses such as malaria, diarrheal diseases, and tuberculosis. Maternal care is of special concern in Ghana, with a non-live birth rate estimated at 14% and a maternal mortality rate estimated at 2.5% as of 2004.⁷ Electrical blackouts are frequent, even in urban areas. Water is not always available from the ground and is difficult to harvest from the rain

without promoting malaria. While there is a measure of economic stability, poverty is common, with a gross national per capita income of about US\$450. Many of the primary healthcare concerns are logistic: simply getting necessary healthcare to the 20 million citizens of Ghana.⁸

Regional variation and the needs of different communities were heavily emphasized during the tour. Institutional primary care facilities are highly varied throughout the country, with dramatic differences in infrastructure, physicians per capita, and patient demography. In Figure 2 are two regional hospitals, St. Francis Xavier in southern Ghana and Komfo Anokye Teaching Hospital, somewhat further north in Kumasi and serving a significantly larger population. Despite significant economic disparity between north and south and urban and rural hospitals and clinics, students found common complaints in all environments: inconsistent electrical supply leading to power surges and equipment damage and lack of supplies for repairs and maintenance. Interviews with maintenance personnel at even major hospitals revealed shortages or absence of tools such as Allen wrenches required to maintain standard medical equipment. The standard approach to repair, as described by representatives of these hospitals, was to ship malfunctioning equipment away for repair, often out of country.



Figure 2 – (left) St. Francis Xavier Hospital in Assin Fosu and (right) Komfo Anokye Teaching Hospital in Kumasi. St. Francis Xavier serves a broad, mostly rural region near Cape Coast while Komfo Anokye serves a much denser urban population.

The state of road infrastructure, the cost of fuel, and hazards created by the rainy season in Ghana often prevent individuals needing treatment from traveling to healthcare centers in more urban areas. To mitigate this problem, the Ghana Health Service has implemented the Community Based Health Planning Services (CHPS) program, in which community health officers (CHOs), individuals with basic healthcare training, are positioned in rural communities to assist in preventative and emergency healthcare. The premise is that healthcare workers embedded in a community, even if working alone, can disseminate information regarding preventative measures (nutrition, hand-washing, water quality, sanitation, malaria prevention, etc.), provide basic and some emergency medical care when transport to a healthcare center is impossible or impractical, and relay information about the health of the community to the Ghana Health Service through cell phones and their motorcycle courier system. In a press release, the

Ghana Health Services credited the CHPS program with a 7.6% reduction in infant mortality in the Upper West Region, where the program was first implemented.⁹

Students spoke with the director of the research center in Navrongo, where the CHPS program is being evaluated, and interviewed CHOs and community members in the village of Nyamkpala, as shown in Figure 3. While utilities were absent at most CHO clinics, their greatest complaint concerned road infrastructure. The roads of much of the rural north are dirt, poorly maintained, and can become impassable in the rainy season. Much of the population, including the CHOs, travel by “tro-tro”, passenger vans meant to carry six to twelve people but which often carry many more. Obtaining new consumables such as sterile bandages and IV fluid is hence very difficult, as only small amounts of material may be carried each trip. Sterilization was also a challenge at these clinics, as chemical means of cleaning and sterilization, such as bleach or ethanol, would also be too bulky to carry on a tro-tro in quantity.



Figure 3 - Students visiting a community health officer in Nyamkpala Village (top), near Tamale, and interviewing community members through a Hausa translator (bottom)

After visiting four hospitals throughout the country, as well as several clinics and NGOs, the students compiled their research for presentation. The conclusion of the abroad Health for All

class consisted of the students presenting their background research to the Minister of Health, Benjamin Kunbuor.

Problem Identification

With the Health for All class concluded, the engineering students were asked to identify design problems inspired by their background research abroad. Each of the two engineering students was responsible for identifying one problem, which that student would then continue into the following semester as part of the Bioengineering Capstone Design course. Each would lead a team of five or six students to develop a technical solution and take it to prototype.

Both students focused on the needs of the Community Health Officers, individuals who provide basic medical care in an environment with many constraints. Electricity and potable water are most likely absent at the clinics in question. All supplies must be rugged and portable by tro-tro. Maintenance must be simple and require only the minimal tools and hardware available in rural Ghana. Clear manuals are required for users who, while trained healthcare professionals, might not be technically savvy or speak/read English as their primary language.

The two problems selected were: (1) to identify a method for creating IV saline solution on-site at the rural CHO clinics, and (2) to develop a method for sterilizing a variety of medical implements including both metal tools and bandages. IV saline solution is a critical treatment method for cases of extreme diarrheal disease, where dehydration makes the patient unresponsive and unable to swallow oral rehydration salts. IV saline solution, being both bulky and having a limited shelf life, is inherently difficult to keep stocked in remote areas. Sterilization of medical supplies at the CHO clinics is most often accomplished by boiling. While this is reasonably effective for metal tools, cotton goods such as bandages are left wet, and drying them in open air re-contaminates them.

Domestic Component

The subsequent semester, Fall of 2010, the two engineering students from Health for All rejoined their cohort for Bioengineering Capstone Design. At Syracuse University, this is a one semester course, in which student teams take a technical problem from initiation to prototype. Projects are normally submitted by researchers or industry representatives from the Central New York area. These individuals, termed 'external clients' in the class, present their problem to the class as a whole in the second week of the term. Students then rank their project preferences, and teams of five or six students are selected based on those rankings. The external clients then make themselves available to advise their respective teams throughout the semester. In the case of the two student-originated projects from Health for All, the students themselves presented their problem statements to the class, and two Syracuse residents from Ghana, Kwame Adusei and Kwame Otioku, a physician and an aerospace engineer respectively, agreed to serve as external clients for the teams throughout the semester.

The sterilization team's prototype may be seen in Figure 4 below. After ideation, the team settled upon a non-electric autoclave as the core of their process. In order to sterilize both metal instruments and cotton goods, the autoclave was modified to possess a drying cycle in the form of a vacuum pump. A high pressure manual pump, commercially available to pressurize air rifle cartridges, was modified to withdraw air from the autoclave after a sterilization cycle. Manual pumping reduces the pressure within the chamber sufficiently to increase the rate of evaporation, thus drying cotton goods over a period ranging from approximately ten minutes to thirty minutes, depending on the bulk of material, without recontaminating the chamber. Due to an increased emphasis on renewable energy in Ghana, driven by deforestation concerns, the team's external client requested that the autoclave be made solar. Parabolic reflectors, insulation, and high-temperature light-absorbing paint were added to the autoclave as well, but these were discarded as solar heating failed to validate.



Figure 4: (left) The sterilization prototype, consisting of a non-electric autoclave, high pressure pump, and equipment to allow solar heating of the autoclave and (right) a team member putting the autoclave through a drying cycle through manual pumping.

The final product met environmental design constraints by utilizing power sources other than electricity, being small enough to be carried in a passenger vehicle easily, and being composed of a small number of robust components requiring minimal maintenance. Further, the manual pump found cultural acceptance, as the pumping action can be likened to the preparation of a Ghanaian dish, fufu. In the preparation of fufu, cassava is pounded in a pestle with a stick roughly the size of the manual pump. Proper preparation of fufu takes hours of pounding, and the ability to do so is considered a sign of a good wife. The Ghanaian advisors suggested that not only would the work of using the pump be tolerable in the rural CHO clinics, but young women might actively seek the labor.

The IV saline team presented a four-part process as their solution, as shown in Figure 5. In order to remove particulates and inorganic contaminants, the first step was a solar distillation chamber.

While small in size, the chamber was estimated analytically at being able to produce 4 liters of distilled water per day under average sunlight in Ghana. Practical validation under sub-optimal conditions produced approximately 1L. This distilled water is then supplemented with commercially available saline tablets. The second part of the process involves filtration through a Lifestraw Family Unit, produced by Vestergaard Frandsen and donated to the team for this project. This is a sub-micron filter designed for developing nations to make non-potable water safe to drink in a single pass by filtering out microbes. It is robustly constructed with a lifespan of several years under normal use, and it is widely available in Ghana. In the IV saline process, distilled water is filtered through the Lifestraw into a boiled 300mL glass bottle of a kind readily available in Ghana. These filled bottles are then capped and placed in a solar disinfection tray, a reflective trough which focuses UV through the bottles, for several hours to eliminate any residual bacteria. Finally, the bottle may be prepared to administer IV fluids with tubing which allows air into the bottle without contaminating the saline solution.

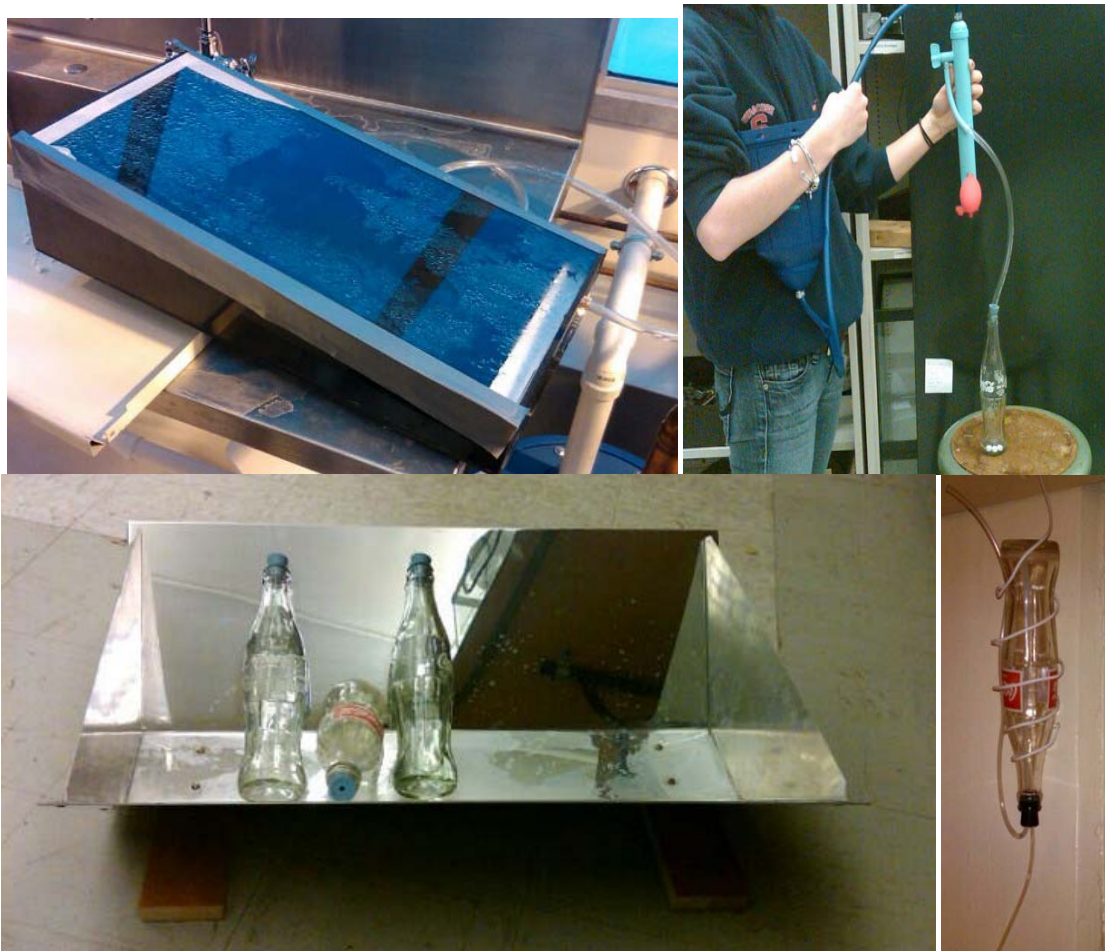


Figure 5: The IV saline prototype utilizing (upper left) a solar distillation system, (upper right) a Lifestraw Family Unit, (lower left) a reflective trough for solar disinfection of saline after mixing, and (lower right) tubing to allow 300 mL glass bottles present in Ghana to be used to infuse saline.

This process meets the environmental constraints of the rural clinics, utilizing non-potable water as source material and requiring no electrical power. While composed of several steps with numerous components, the components are all available in Ghana, and the devices could easily be built from scratch there. While approval for medical use would take several years and only after significant refinement of the design, the students did perform a cursory validation study measuring salinity and pH and comparing the output of their system to standard sterile saline solution using bacterial stains. They found the synthesized saline equivalent to the standard in three out of four samples tested.

Project Conclusion

At the conclusion of the Bioengineering Capstone Design course, additional funds were made available to allow two students, one of whom had been in the summer course, to travel to Ghana to present their prototypes to representatives there. Figure 6 displays the presentations to the Water Resources Commission in Accra. Responses were extremely positive, with audience members commenting on the students' extensive knowledge base regarding Ghana. Of note, both prototypes were damaged during travel to Ghana, and, as a test of the prototypes' ease of maintenance, the students were tasked with repairing them using parts from Makola Market, an extensive open air market in Accra. Both succeeded in repairing the prototypes and performing a validation test on-site.



Figure 6: A representative from each of the design teams presenting to the Water Resources Commission in Accra.

Discussion

The two projects used as a case study here both demonstrated consideration for design in a global setting, cultural sensitivity, and atypical enthusiasm by the design teams involved. The five week experience in Ghana allowed the two team leaders to gain sufficient context to formulate realizable design problems. This background knowledge also informed design constraints to a greater depth than achievable with internet searches, for an environment very different from

Central NY. Further, the two team leaders were able to not just define constraints but recognize the strengths and resources of the environment and culture for which they were building. Rather than focusing on the lack of electricity in rural clinics, the sterilization team recognized that they had resources available to them in the form of manual labor and a pragmatic culture in which such manual tasks are not considered tedious. The IV saline team recognized they had an extensive list of supplies to build from, and they based their design entirely on parts obtainable in rural Ghana. Where the two team leaders brought contextual knowledge, the rest of the team members brought enthusiasm, expressing appreciation that they were building for a real environment and questioning the team leaders at great length about their experience. As such, there was an effective amplification of the abroad experience – while only two students could participate in the summer course abroad, nine other students were able to benefit from their experience.

While the Health for All Summer course and the Bioengineering Capstone Design Fall course are both inherently healthcare-related, other engineering disciplines could also have drawn design topics from the abroad experience. For instance, electrical engineering students could have worked on protecting instruments from the powerful surges common in Ghana or been inspired by any of a number of NGOs working on alternative energy there. Civil and environmental engineers would have had a plethora of options, as many of Ghana's major health concerns (malaria, diarrheal disease, maternity issues, etc.) are addressable by changes in infrastructure as well as healthcare.

Further, with a determined student and some guidance from an engineering faculty advisor, it might be possible to associate problem identification with a wide array of study abroad experiences. A productive method of identifying potential design class problems is simply to interview people working in the relevant field and solicit their complaints about the status quo. This sort of problem identification search could be done coincident to other unrelated study abroad experiences. For instance, a bioengineering student from the US studying Mandarin in China could also interview physicians as part of an independent study in problem identification.

Study abroad is inherently costly, and financial limitations may prevent this type of collaboration from becoming commonplace or repeatable. For this collaboration, some financial support was provided to the students participating in the abroad component. Travel abroad to Africa in particular can be prohibitively expensive for students, and numerous students who expressed interest in the Ghana course relayed that they would require financial assistance to participate. However, the actual financial assistance provided to the two engineering student participants was not total, only covering their tuition for the Health for All course and excluding airfare, lodging, etc. Students were extremely receptive to this limited financial assistance, regarding it as a discounted study abroad experience. This suggests that small amounts of supplemental funding may have a disproportionate effect on encouraging student participation in the abroad component.

Future Work

The initial program gave a proof of concept that abroad programs can be used to enrich the capstone design course experience without creating new abroad courses or making extensive changes to existing ones. Two avenues will be pursued to continue the program. The collaboration may be expanded to include other departments within the School of Engineering at Syracuse University. The Health for All course is scheduled to resume in the summer of 2012, and representative students from several engineering departments could be encouraged to participate. In addition, more Syracuse University Abroad courses may become involved, some of which engineering students already participate in. Each semester, several students in the School of Engineering participate in abroad programs to countries such as China, Spain, and Turkey on their own initiative without any special financial assistance from the School. Independent study credits on problem identification performed coincident to these abroad experiences may be possible. It would not require many participating students to make a significant difference. The greatest potential offered by these collaborations is that of amplification. Each student participating abroad serves to enrich the design course experience for an entire design team and, to a lesser extent, the entire Capstone Design class.

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