# AC 2011-763: A GUATEMALAN IMMERSION FOR TEACHING ENGINEERING DESIGN PRINCIPLES TO HIGH SCHOOL STUDENTS

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# A Guatemalan Immersion for Teaching Engineering Design Principles to U.S. High School Students


## Abstract

In the summer of 2010, a unique high school program was launched to promote STEM topics in the area of health care by highlighting challenges in developing countries. High school students from around the United States were selected for a month long STEM experience in the chosen site of Calhuitz, Guatemala, a remote community in the county of Huehuetenango. A team of Bioengineering and Nursing faculty delivered this educational and cultural summer experience with the objective to broaden students' knowledge and exposure to health care careers in engineering and nursing, while providing assistive devices and health care outreach to the local community. The high school students convened for two and a half days on the campus of Florida Gulf Coast University (FGCU), where they were introduced to health care topics and prepared for the challenges they would encounter in Guatemala. Students spent three and a half weeks in country where they learned about nursing practices, community assessment, medical instrumentation and engineering design principles, with much of the learning facilitated through small group, community-based activities. Students concluded the trip back at FGCU, formally presenting their work to local community members, from the campus and the greater Ft. Myers and Naples area; students were also interviewed by these community members one-on-one to determine successes and areas for improvement in the program. While the paper will summarize all components of the high school program, the focus of the paper is on the design topics introduced in Guatemala, including activities used to teach and learn engineering design, the in-country design project completed by the high school students, and the design projects launched at the undergraduate level as a result of the summer program.

Design components were introduced in two ways with the high school students. In small groups students learned about interviewing clients, identifying problems, writing subsequent need statements from these problems, and brainstorming solutions. These components of the design process were introduced by interviewing clients, often with severe medical conditions, and through discussions immediately following the interview. In large group sessions, the faculty members more formally introduced and discussed these design components and continued the design process by selecting one case study and identifying needs; students created specifications, brainstormed alternative designs, and designed and built a final product that was delivered to the client at the end of the program. The students completed this project under the constraints of using locally available material and on a $50 budget. The paper details these activities used for both the small group, case-study interviews and the large group design build. Assessment of actual and perceived gains in engineering design topics were performed through Likert surveys of students and student comments. The paper concludes with reflections on improvements for the next summer program.

**Program Summary**

A team of Bioengineering and Nursing faculty at FGCU and Duke University collaborated to develop a high school program that introduced STEM topics in health care in a setting that students may not have otherwise considered or experienced as a teenager. Faculty at FGCU were awarded a four-year grant from Global Public Service Academy (GPSA), to teach elements of nursing and engineering to high school students from the United States in a setting that provided a unique cultural experience for the student. The program, which took place in the chosen community of Calhuitz, Guatemala, had two over-arching objectives: (1) to broaden high school students exposure not only to traditional health care careers in medicine, but also to the integration of health care in the sciences, engineering, and math by providing an educational experience in a developing country, and (2) to improve healthcare of the local community through the development of assistive devices and community assistance in health care delivery especially at the Casa Materna, the regional maternal child health clinic. This first year was conducted as a pilot project with reduced funding and smaller number of students. Students accepted into the program, with expressed interest in health care related careers, engaged in a four week program which included three days on campus preparing for the site visit, three weeks on the ground in the small community of Calhuitz, Guatemala, and a post-trip workshop back on FGCU's campus to summarize projects from the visit and to receive mentoring on their college applications. Following is a brief summary of the experience:

*Pre-trip Experience*: The initial on-campus program included (1) learning how to take physical measurements and why these are important to scientist and engineers as well as clinicians, (2) participating in a case-study to learn how to ask the appropriate questions regarding a person's physical disabilities and assistive device needs, and (3) an introduction to journaling and "tweeting," which was the students only means of communication with family and friends during the program. Students also toured the campus and met with college students in engineering.

*Guatemalan Experience:* Students spent three weeks in the community of Calhuitz, living at the local community center and working at the Casa Materna and the community at large. In the mornings students divided into three groups and spent a week with a faculty mentor on different daily assignments/activities. These activities included: (1) facilitating waiting room screenings, (2) shadowing a nurse or health practitioner and providing assistance as needed, (3) taking part in post-clinical consultations, (4) assisting in providing community training on essential topics such as hygiene and nutrition, and (5) meeting with villagers to document assistive device needs. After lunch, students participated as a group in more formal educational lessons, which included nursing and the delivery of health care, engineering design, and engineering instrumentation. These were conducted as active learning sessions, with labs and activities included in each presentation. In the late afternoon, students and faculty participated in an hour-long Chuj lesson, which is the native language of the region. One of the Calhuitz community members taught the

group in Spanish and provided the equivalent Chuj word or phrase. After dinner, the group reconvened to discuss a book about the Guatemalan culture and history or to listen to one of the many Calhuitz community members who provided talks about the civil war, religion, water resources, and health care (to name a few). Evenings concluded with journaling and tweeting.

*Post-trip experience*: Upon returning to campus, students were assigned a topic for a culminating seminar for invited guests, and students presented their activity in a PowerPoint or poster format. This was also a time to assess the students opinions of the program, and each were interviewed by one of the invited guests. During this final day and a half, students also received coaching on their college applications, with attention to their written essays.

**Teaching Design with Focus on Developing Countries**

In particular to the design component of this program, the purpose of the small group activities was to identify client based needs focused on adaptive devices, such as a walking device or a tool to assist a person with everyday tasks. Two engineering faculty members led the engineering design, small group sessions. The instructors delivered the design content in two formats. Small group sessions started with interviewing the client and families at their homes; then the faculty members stepped the students through a problem and needs identification process and finished the sessions with students brainstorming ideas for one of the needs. Students rotated through these sessions in groups of two or three. Each group interviewed two clients and attempted to identify needs and alternative solutions for the needs. The other format for teaching design was with the full group of high school students. The large group sessions detailed the design progression and provided an explanation of the design process with integrated activities based on one project. The focus of the large group sessions was to identify one client and one specific need and to design a solution for that need using only locally available materials and tools. The following sections detail each format.

***Small Group Sessions***

Prior to leaving for Guatemala, students received tips on interviewing clients and watched a video discussing various projects that have been launched out of problems identified in developing countries. The students then practiced their interviewing skills by asking questions of one of the instructors who role played an ailment. In country students started each morning in the small group sessions. The students were divided into groups of two to three students. One criterion in team assignments was student fluency in Spanish. The interviews with clients and their families at their homes enabled the students to see the various physical and mental handicaps of the clients. Students were responsible for asking questions, including finding out about the medical condition and identifying problems and needs of the individual or family. Questions were asked in Spanish by one of the students and translated by a community liaison

and interpreter to Chuj; replies were often in Chuj and then translated to Spanish. Figure 1a is a photo taken from one of the client interviews and includes the students and the interpreter. Students also documented the questioning in a logbook and with video recording and pictures, as is seen in Figure 1a.

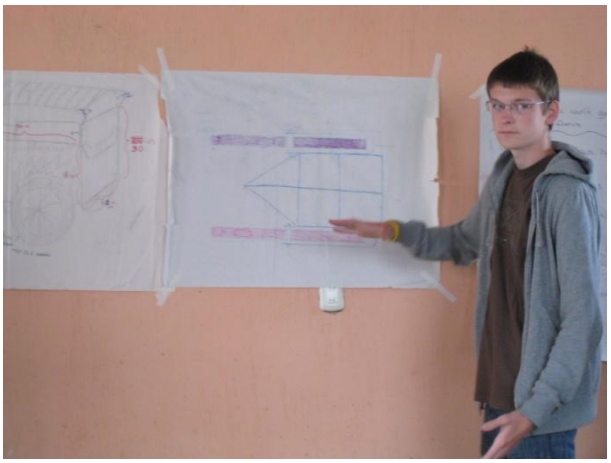
Upon returning to the community center, the group reflected on what they saw since many of the situations were sad in terms of the ailments and living conditions. The group stepped through the initial steps of the design process by listing as many problems as possible in a brainstorming session (Figure 1b). The instructors then discussed writing need statements for each problem to help begin the process of writing specifications. The students concluded these activities by documenting in their notebooks and on the computer the interview session and the results of the design process. This became the basis for the design projects that were introduced to the undergraduate students at FGCU for their fall design courses. Aspects of the undergraduate portion of these projects are discussed later in the paper.

Figure 1a: Interviewing the client. The small group worked with the interpreter to identify the medical problems and client's needs. Figure 1b: Brainstorming solutions. Back at the community center, the instructors stepped through the initial phases of the design process with the students. Here the students brainstorm ideas for an assistive device

Each team provided needs statements, problem constraints and criteria, and supporting materials such as interviews and videos by the end of the program. The project ideas were summarized and specific projects were identified as suitable for a two course sequence in Engineering Service Learning and Engineering Entrepreneurship; other projects were identified as feasible for the in-country design experience and were presented during the large group design session, which is discussed next.

***Large Group Sessions***

The design instructors had approximately a week to meet with the students in a large group and teach components of design with relevance to the developing country. The instructors prepared a series of sessions with integrated active learning sessions. Using case studies from the first week of interviews with two families, the instructors identified a problem from one of the families and used this as the impetus for teaching design. The students, in the first small group who conducted the interview, introduced the medical conditions of the person and discussed the various challenges that this person and family faced on a daily basis. The instructors selected one problem, which was enabling the family to transport their physically and mentally handicapped daughter with them to church and the market. The faculty then guided the students through identifying needs, writing initial specifications, brainstorming designs, developing a list of materials, and finally building the assistive device for the family/child. Several alternative designs were initially discussed, with a final design selected based on locally available material and tools. Figures 2a and 2b highlight one design session in which students pitched their design to the other team.



Figures 2a & 2b: Pitching their design. Students brainstormed various solutions for transportation and agreed that a rickshaw design would be most suitable based on the needs and the initial specifications. Here the students present their initial designs for their cart.

With the final design concept selected, the students spent three sessions purchasing and finding locally available material, meeting with a welder to help fabricate the frame, and building the "seat" for the cart shown below. At the end of in country stay, the students presented their cart to the family. Figures 3a and 3b illustrate this process while Figure 4 shows the final product, a cart that enabled the family to transport their daughter on the local roads of Calhuitz. Exit interviews from the students indicated this was a valuable and memorable experience for the students.


Figure 3a & 3b: Fabrication. The picture on the left was taken at the welders who assisted in attaching the frame to the bicycle tire rims. On the right, the students used resources from the community to construct the seat.


Figures 4a & 4b: Final Product. The students delivered their final design to the family during the last day in Calhuitz. Here the daughter sits in her new cart and her father demonstrates its use. The students designed the cart using locally available material and with consideration of the terrain in Calhuitz.

**Assessment of the Program**

The students took a survey that included the series of topics covered over the four week program. The topics ranged from the students familiarity with engineering design, team work, and the bioengineering profession, to name a few. The full questionnaire is provided at the end of this paper for reference. The survey was taken prior to delivery of any design or engineering topics and at the conclusion of the program. Table 1 documents the average difference between the pre-experience and post-experience questionnaire, which specifically targeted the engineering design experience.

Table 1: Assessment Results. This table details the average difference between the pre and post-assessment of the students' knowledge of each topic.

| Topics | Average difference pre and post-experience |
|---|---|
| Engineering design | 1.625 |
| Team work | -0.0625 |
| Design and assemble simple projects | 0.4375 |
| Needs assessment | 1.625 |
| Stakeholders | 1.25 |
| Brainstorming | 0.625 |
| Define constraints and specifications | 0.75 |
| Develop constraints and specifications | 1.25 |
| Concept evaluation | 0.875 |
| Sustainable design | 1.875 |
| Poster presentation | -0.25 |
| Career planning | -0.125 |
| Bioengineering | 0.6875 |
| Bioengineering as a profession | -0.375 |

The results of the assessment indicate that the students improved their understanding of most topics but especially in engineering design, needs assessments, stakeholders, defining constraints and specifications, and sustainable design. Students indicated no improvement in skills such as team work and poster presentations, likely because these students were already well adept at these from their educational experience. Career planning was not emphasized as a topic in the program, but professors assumed an in-direct education of bioengineering since three of the four faculty members were bioengineers. Students did not understand what bioengineering was as a discipline or a profession, so future sessions will include an overview of the discipline as a whole. Most of the students self-identified as being interested in the clinical side of health care, including nursing and medical school, but one of the focuses of the program was to highlight the engineering side of health care.

**The Next Design Phase**

Three of the identified projects from Guatemala have been implemented into the Engineering Service Learning and Engineering Entrepreneurship courses. The student based projects will be completed by April 2011. Final products will be delivered to the clients as part of the summer program. One of these projects includes an improved cart design to replace the cart built by the high school students. The goal is to identify new projects each year to be implemented in the design sequence at FGCU. The authors intend to write-up project results for a future publication.

## Lessons Learned

Two primary challenges have been identified and will be addressed for subsequent offerings of this program. The first challenge was the identification of appropriate clients. The focus of the engineering design process was on adaptive devices. The intent was to design assistive devices such as walking devices, mobility carts, tools or other products to assist in daily activities. Many of the clients met during the interviews suffered from cognitive disorders, for which assistive devices were not appropriate. This was discussed with the liaison while in Guatemala, and it is believed that more appropriate clients will be identified in the future. A second challenge was appropriate documentation of the needs, in particular for projects being brought back for implementation by the undergraduate students. Since faculty from FGCU will rotate through in traveling to Guatemala, the authors need to have a consistent record of the projects returning from the summer program if they are to implement these as possible student projects in their design courses. A template will be developed to provide standard documentation for all projects that assists in detailing the problems and needs of the clients. Procedures will be developed for video documentation, so the video and written report present a clear story of the client's needs.

## Conclusion

Bioengineering and nursing faculty at FGCU and Duke collaborated as a team to develop a unique educational and cultural experience in the developing world for high school students interested in health care careers. This summer program was funded by the Global Public Service Academies, which is a private entity that funds unique programs to introduce U.S. high school students to STEM fields while assisting communities in developing countries. The FGCU-GPSA summer program launched its first trip this year to Calhuitz, Guatemala, with two over-arching objectives: (1) to broaden U.S. high school students' exposure not only to traditional health care careers in medicine, but also to the integration of health care in the sciences, engineering, and math by providing an educational experience to be remembered for a lifetime, and (2) to improve healthcare to the local community through the development of assistive devices and community assistance, especially in the area of maternal-child health.

Engineering design was one of the central educational focuses for this summer session. The authors delivered lesson content through small group activities and client interactions and with large group, structured lessons that led to the development of an assistive device for a local family. Students showed an increased gain in knowledge of several key aspects of engineering design. Several students also indicated that building and delivering the cart was the highlight of their summer experience. The design sessions will be included in subsequent summer programs with attention made to the consistency of the documentation for clients' needs; this is to ensure a full understanding of the problem exists after each small group session, so that projects are fully understood at the university level by those not participating in the summer sessions.

Name _____

Pre (and Post) Program Assessment

Enter a score that best describes you right now.

| | Accomplished (4) | Competent (3) | Developing (2) | Beginning (1) | Score |
|---|---|---|---|---|---|
| **Engineering Design** | I have used the engineering design process extensively and believe I have a thorough understanding of how and why it is important. | I have used the engineering design process and have a basic understanding of why it is important. | I have heard of the engineering design process but have not used it and do not understand the difference between the design process and the scientific method. | I have never heard of the engineering design process. | |
| **Team work** | I have worked on teams extensively and believe I am capable of leading a team to a successful conclusion as well as serving as an effective team member | I have worked on teams and have been an active team member however I have minimum experience leading teams | I have worked on teams as a passive team member. I am ready or almost ready to become a more active team member | I have minimal team work experience and am not comfortable taking an active role on a team | |
| **Design and assemble simple projects** | I have extensive experience designing and assembling projects, both simple and complex, which I have designed or helped design | I have experience designing and assembling simple projects which I have designed or helped design | I have minimal experience designing and/or assembling simple projects | I have no experience designing and/or assembling simple projects | |
| **Needs Assessment** | I have experience doing needs assessments and I have experience interviewing people with the purpose of identifying needs | I have minimal experience doing needs assessments and I have some experience interviewing people and would be comfortable interviewing with the purpose of | I have no experience doing needs assessments however I am comfortable interviewing people with the purpose of identifying needs if provided specific | I have no experience doing needs assessment and am uncomfortable interviewing people with the purpose of identifying needs unless | |

| | | | | | |
|---|---|---|---|---|---|
| | | identifying needs with appropriate guidelines | guidelines | accompanied by an experience interviewer | |
| **Stakeholders** | I understand what stakeholders are, how to identify them and why it is important to include them in the design process | I understand what stakeholders are and why they are important however I am unsure of how to appropriately identify them | I have heard the term "stakeholder" and believe I know what they are | I have never heard the term "stakeholder" | |
| **Brainstorming** | I have participated in brainstorming sessions, understand the rules of brainstorming and use the techniques to approach design activities | I have participated in brainstorming sessions and understand the rules of brainstorming | I may have participated in brainstorming activities without knowing it | I have never heard the term "brainstorming" | |
| **Define constraints and specifications** | I understand the difference between constraints and specifications and can identify constraints and specifications for the purpose of design | I think I know the difference between constraints and specifications | I am familiar with the terms constraints and specifications but am unsure I can tell the difference | Constraints and specifications are different? | |
| **Develop constraints and specifications** | I am capable of writing/developing constraints and criteria for design projects | I think I can write/develop constraints and criteria for design projects | I think I can write/develop constraints and criteria for design projects with assistance from a person with experience | What are constraints and specifications | |
| **Concept evaluation** | I have done concepts evaluation using specific tools such as Pugh charts, pro/con lists or other appropriate tools | I have done concepts evaluation using specific tools such as Pugh charts, pro/con lists or other appropriate tools | I have never done concept evaluation however I have heard if tools such as Pugh Charts or pro/con lists | I have never done concept evaluation nor have I have heard if tools such as Pugh Charts or pro/con lists | |

| | | | | | |
|---|---|---|---|---|---|
| **Sustainable design** | I know what sustainable design is and have used sustainable design concepts in a recent design project | I know what sustainable design is and have read about sustainable designs | I am somewhat familiar with the term "sustainable design" | I have never heard of the term "sustainable design" | |
| **Poster presentation** | I have extensive experience designing technical posters and presenting posters | I have some experience designing technical posters with presentations | I have limited experience designing posters for presentations | I have never designed a poster for a presentation | |
| **Career planning** | I know, with certainty, the career I plan to pursue and have a plan in place (identified schools, programs…) | I think I know the career I plan to pursue and have some idea of what steps are necessary to be successful | I think I know the career I plan to pursue but have not spent much time planning my next steps | I have no idea what I want to do in the future | |
| **Bioengineering** | I thoroughly understand profession of bioengineering (biomedical engineering) and feel comfortable explaining bioengineering to others | I understand the profession of bioengineering however would not want to explain it to others | I think I understand the profession of bioengineering | I really do not know what bioengineering is | |
| **Bioengineering as a profession** | I am planning on pursuing bioengineering as an undergraduate major | I have considered pursuing bioengineering as an undergraduate major | I have considered pursuing engineering, not necessarily bioengineering as a career | I am not interested in engineering | |