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RUNNING UNDERGRADUATE PROJECTS IN DEVELOPING COMMUNITIES: IMPLEMENTING A HEALTHCARE INFORMATION SYSTEM IN A HISPANIC, BORDER COMMUNITY

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ABSTRACT
An information system was designed for a non-profit organization located in an international, developing community for an undergraduate engineering course. The project team went through the process of identifying needs, generating concepts, selecting a design, and implementing and testing the final design. In this paper, similarities and differences of this project compared to other projects in the course are explored. The team was confronted with unique problems resulting from working with an international sponsor in a developing community. Communication and donations of varying types were important players in overcoming these obstacles.

INTRODUCTION
An undergraduate team of four was given the task of designing a new system of gathering and storing information for a non-profit health services organization located in Nogales, Arizona. Throughout the design process, the team was challenged with several problems that arose because the client was from an international, developing community. For example, due to the client's technologically-limited background, they had unrealistic expectations for a two-semester, four-person design project. The service aspect of the project introduced issues as well. An incomplete project was not acceptable and the client would need support for the system. These issues, how they manifested themselves through a design process, and how they were addressed are the focus of this paper.

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FRAME OF REFERENCE

Interdisciplinary Design at the University of Arizona
ENGR 498, Cross-disciplinary Engineering Design, is a two-semester course at the University of Arizona in which teams of students from different majors work with a project sponsor on a single design project. A highly abstracted version of the design process taught in ENGR 498 is shown in Figure 1.

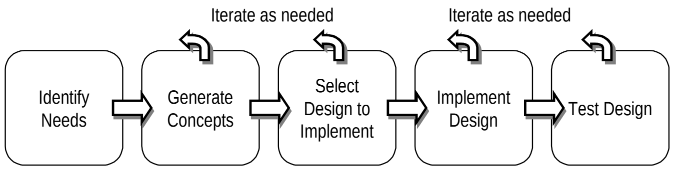

Figure 1 Design Phases in ENGR 498

Design teams start by identifying the needs of the client. With needs clarified, a design team will generate concepts and select one design that best meets the needs of the client. Most teams generate many ideas, select two to three to pursue further, refine and do trade studies on those two to three concepts, and then narrow to one final design by the end of the first term. In the second semester, design teams implement their designs and test them against the customer needs. By the end of the second semester, student design teams are expected to have a final design that is built and tested.

Most projects in ENGR 498 are sponsored by companies such as Lockheed Martin and Raytheon. Each year, however, several non-industry projects with strong service-learning characteristics are run in the course. One such project, the Nogales Information Systems (Nogis), is the focus of this paper because its client is located in an international, developing community.

Service-learning in Engineering Design

The Nogis project is an example of service-learning in engineering education. Service-learning can be defined as "a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development" [1]. Underrepresented in this definition is the importance of *identifying the needs* of the client. One assertion made in this paper is that, due to the unique attributes of many clients in service-learning projects, the *identification* of needs is an especially important step.

In engineering, design courses provide the most fertile ground for service-learning experiences. Two prime examples of this are the Engineering Projects in Community Service program at Purdue University [2] and Engineers Without Borders [3]. The Nogis project presented here is another example of a design-related service-learning project.

Much research has been performed on the effects of service-learning on student learning. Of particular interest here is the research on service-learning's impact on students' views on their social responsibility as engineers. Two large scale studies show that service-learning experiences positively affect students' academic learning, interpersonal skills, and sense of responsibility to society [4-5]. Other work shows that students participating in service-learning experiences participate in class more, show increased sensitivity to societal issues, and are more skilled at understanding persons different from themselves [6]. While these previous studies rely on large numbers to provide statistical relevance, the work here is presented as a case study, where relevance and meaning is gleaned from an in-depth analysis of a small number cases (in this case, n=1) [7].

NOGALES INFORMATION SYSTEMS PROJECT

The Way of the Heart: The Promotora Institute (WHPI) is a non-profit healthcare organization that provides healthcare services in "Ambos Nogales," a border community spanning Arizona, USA, and Sonora, Mexico, using a network of lay healthcare workers to educate and provide basic medical services to members of the community. Promotoras serve a range of individuals with healthcare needs in both Nogales, Arizona and Nogales, Sonora. The lay healthcare workers are known as "promotoras de salud," Spanish for promoters of health. There are less than ten women at the WHPI.

A team composed of two students from systems and industrial engineering, one from computer science, and one from management information systems was formed to work on the Nogales Information System (Nogis) project in senior design. Prior to that class, two of the students worked during their junior year (with several others) to gather requirements and needs. The goal of the Nogis project was to design and implement a networked, computer-based, database-driven, novice-friendly information system that would facilitate office processes. Currently, patient information at the WHPI is recorded by hand and stored in filing cabinets. The WHPI uses the information they obtain to produce reports which they use in applying for grants. Compiling the data from their paper records for the reports is a time-consuming process. A computer-based system would allow them to generate statistics and relations quickly.

This project was different than most projects in the class for several reasons. First, the client did not have a technical background. This would also be true of domestic projects such as those with non-profit organizations or communities. Secondly, the client is in an international community. While the actual location of the WHPI facility is within Arizona, it is on the border of Mexico and the culture of the community is strongly influenced by this proximity. Thirdly, the client works within a low-income, "developing" community. In many cases, individuals in these border communities are in transition, resulting in difficult living conditions that affect healthcare, housing, and quality of life.

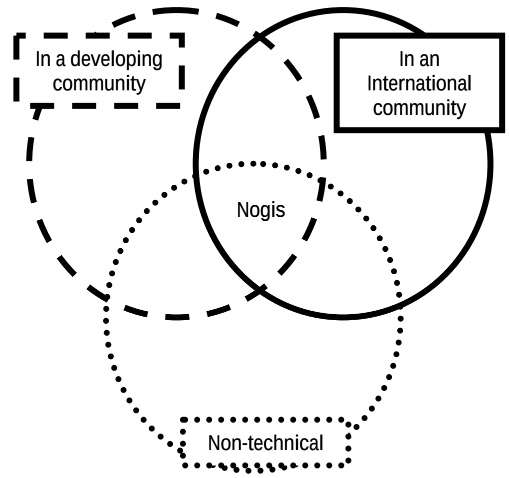

Figure 2 Unique Attributes of the Client for the Nogis Project

Taken together, these three aspects of this client, shown in Figure 2, are applicable to many service-learning projects in developing communities throughout the world. Hence, lessons learned from this experience are applicable to a wide range of cases.

Requirements

Customer requirements were gathered for one year prior to the design and implementation of the information system. As a part of a junior-year service-learning program for women, a team of women engineers organized and implemented a workshop in Nogales, Arizona to gain stakeholder input on the ways that technology could support healthcare needs along the border. Participants in the workshop included university engineering and public health faculty, Nogales, Arizona medical professionals (doctors, nurses, promotoras, school nurses) and Nogales public outreach professionals. An inclusive process that allowed multiple stakeholders in border healthcare issues to actively participate in defining areas where technology development would be most meaningful is different than most industry engagements, where clients have a firm sense of what technology can offer and a clear sense of requirements for delivering technologies. Further, the border area is traditionally a technology-poor area, meaning that individuals are not generally in a position to procure or develop technologies to fulfill needs, and nor do they often consider where technology could be most useful. As an outcome of this workshop, the team of women engineers selected a project focused on supporting the WHPI, and then spent a semester targeting that provider, interviewing and observing work, understanding customer needs, and developing a requirements document.

The customer setting had challenges unique to the border region. For example, while one of the women engineering students spoke fluent Spanish (being from Hermosillo, Sonora), other members of the team had limited use of the language in a setting where Spanish was generally the dominant language. Most promotoras were bilingual, but preferred Spanish. Further, few of the women on the team had had prior experience with border communities and the "reality" of the border. As such, there was learning that needed to take place to both dispel preconceptions and build understanding about the WHPI mission/clientele, and lives on the border.

A key element of the year-long requirements gathering was to establish and build a relationship with the non-profit organization that would then extend into the senior-year design project. This long-term relationship with the client was seen as critical to then delivering a product that would be useful and effective in the WHPI work setting, and that respected the need for technology appropriate for this setting.

The key requirements of the system are as follows:

- The system must store information pertaining to a health client and all related health cases.
- The information must be searchable and retrievable.
- The system must be bilingual (English and Spanish).
- The system must be easy to use because the users come from a technologically-limited background.

Design

A two-tier architecture was chosen for the information system. The two tiers are the system interface mixed with business logic and the data access layer. The system interface interacts with the user. The business logic enforces business rules. The data access layer communicates with the database. Different approaches were taken for developing the system interface, business logic, and data access layer. The business logic and data access layer do not directly interact with the user and therefore their development occurred as it would for any project. However, the customer's uniqueness had a great impact on the system interface of the final design. The two-tier architecture used is displayed in Figure 3.

The next step in designing the system involved constructing the entity relationship diagram (ERD) for the database. The customer's requirements were used to make decisions concerning tables and relationships.

User interface prototypes were the final stage of design. A scientific method approach was taken to accomplish this. The initial ideas for the user interface were based off of what is common in present software, with the hypothesis being that they would work well for the Nogis client. The ideas were transferred to lo-fi prototypes (i.e., paper). The prototypes were created using graphics software and required no programming. The initial prototypes were tested by presenting them to the client. Positive and negative feedback was received from the client. The feedback was used to make changes and additions to the current design. As feedback was processed, the new design would be presented to the client. This cycle was repeated until the client gave full approval to the design. Originally, a wizard format was designed for inputting information about a health case (as show in Figure 4).

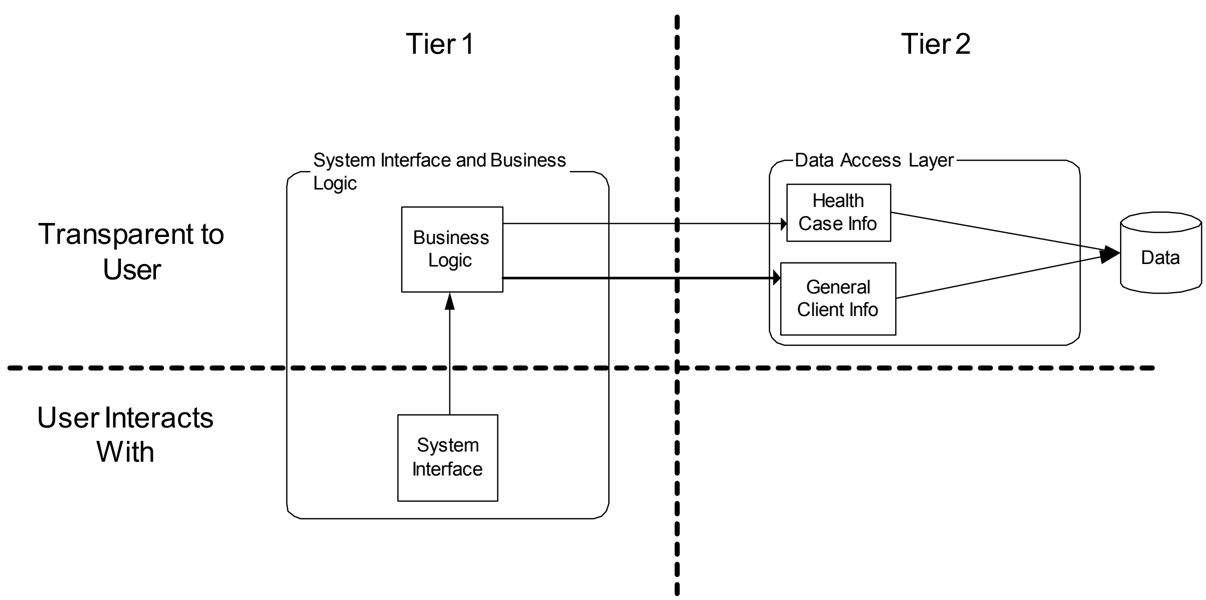

Figure 3 Two Tier Architecture

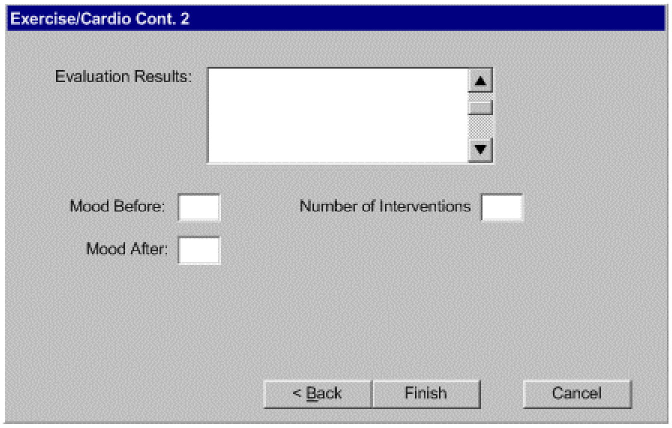

Figure 4 Initial Prototype Using Wizard Format

The client did not like this design because it requires more maneuvering for inputting the information and all the information was not displayed on one screen. The client wanted a format similar to their paper forms. For this project, the client desired a technologically advanced tool that mimicked their current, low-tech paper system. More generally, it is critical for design teams working with non-technical clients to understand how their client can most easily relate to technological designs and integrate them into their culture. The final user interface design is shown in Figure 5.

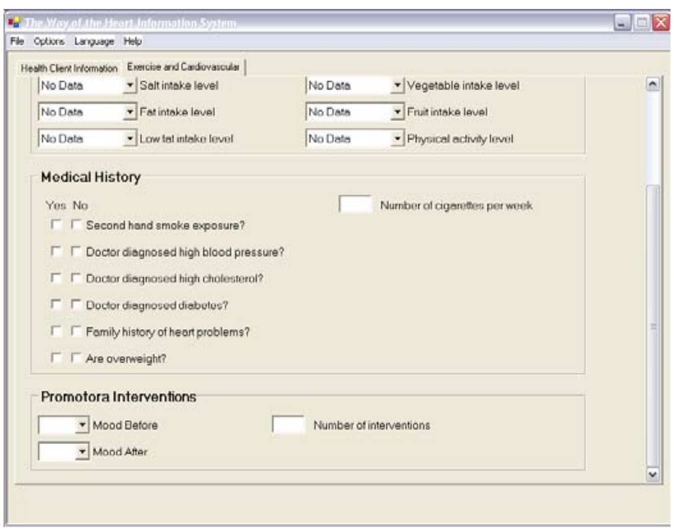

Figure 5 Final System Interface Design

Implementation & Testing

A series of steps were taken to implement and test the final design. The data access layer was completed first. Modules within the data access layer were tested as completed. Testing programs were written. The output each test produced was compared with expected output. If the output did not match, the test failed. If modules failed they were updated and retested. This process was repeated until each module in the data access layer passed all of its tests. A short example of this process is a test case would attempt to edit 1000 records. The before and after state of the records were compared. If they were different and the records contained the correctly updated information, the test passed. If the records information had not been correctly edited, then the programmer would search for the problem. Once they thought the problem had been fixed, the edit test case would be rerun.

The next step in implementation and testing was the system interface and business logic. The lo-fi prototypes were used to create the system interface. As modules for this tier were completed, team members not programming were responsible for testing them. If testers found bugs they would report several bits of information to a bug tracking system.

DISCUSSION

Because the client for the project operates within a developing, international community and does not have a technical background, many aspects of the project were different. Interestingly, however, several aspects of the project proceeded no differently than if the client were an engineering company.

How this Project Was No Different Than Others

The primary common element between this project and more traditional senior design projects was the overall design process. As shown in Figure 1, the phases of design proceeded through include need identification, concept generation and selection, and design implementation and testing. International or not, developing or developed, non-technical or technically-advanced: the process applied is the same at this level of abstraction. This is important because a core objective of ENGR 498 is for students to learn this process through experiences in a design project.

Another interesting point is that components of a design that are transparent to the user are not necessarily affected by a client being international or non-technical. In this project, the business logic and the data access layer are completely transparent to the user and, therefore, could be developed in the same way they would be for a domestic, technically-proficient client. The key component of the Nogis project that the user interacts with is the system interface. The system interface, as is discussed in the next section, is greatly affected by the client.

How this Project Was Different Than Others

While the top-level design process followed in the Nogis project was no different than other projects in the class, the details of how this design process was applied for Nogis was quite different. The key areas of the design process that were most affected by the client being international and non-technical are, not surprisingly, those where client interaction was needed. In Figure 6, elements of the design process that relied heavily on client interaction are lower, while those that could be conducted with little client interaction are higher.

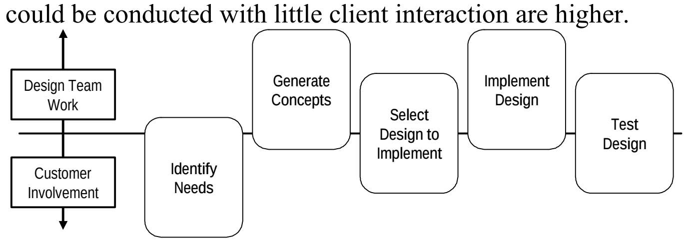

Figure 6 Design Process Related To Client Interaction

The client is most strongly educating the design team in the first phase of need identification. The client is the expert with regards to the needs. Concerning the concepts and the implemented design, it is the responsibility of the team to educate the client. The design team contains the experts with regards to their ideas or the built design. In concept selection and design testing, there is a strong exchange of information between client and design team.

Having a team of engineering students dedicated to gathering customer needs and developing a careful technical requirements document with the customer before implementing a design in the senior design project is of particular importance in working with non-technical customers. Need identification is heavily dependent on interactions with the client and hence was conducted differently for Nogis than it would for a traditional senior design project. It is very difficult for a team of engineering students to understand fully the needs of lay healthcare workers in an international, developing community. Just as the healthcare workers are unfamiliar with the technical aspects of the project, the design team is unfamiliar with the non-technical aspects. Each group needs to educate the other throughout the design process.

The process of need identification was made more complex with the WHPI project, as students needed to organize visits to Nogales, Arizona, 1.5 hours south of Tucson, and to commit time to understanding customer needs in a bilingual, bi-cultural setting that was foreign to them as urban, anglo females. "Professionalism" in a WHPI setting was quite different than the professionalism of running a meeting in a Tucson business office. Having one member of the team who was Hispanic was a huge asset in providing linguistic and cultural translation to the team. Two of the junior-year requirements team continued to work with the project in their senior year.

Concept selection and testing were also unique for this project. As indicated in the previous section, a large part of concept selection involved the use of lo-fidelity prototypes to get feedback from the client as to what was easiest to use. Because the client had a limited technological background, the user interface needed to be simple. The user interface prototypes went through a series of redesigns because they were not simple or intuitive enough. They had been designed through the eyes of advanced users. The design team needed to role play a novice user to design the proper interface.

A lesson learned by the students is that the best solution for people familiar with using technology in their life is likely not the best solution for a technologically-limited population. The "best technology" may not be the best solution. Through addressing this issue in their project (e.g., with the lo-fidelity prototypes to get feedback from their client), the students obtained direct experience with finding the appropriate technology boundary for their project and understanding its impact on their design.

Originally, the project had a much larger scope. The project included all features that the client had specified during the need identification stage. Because the team was not aware of a reasonable scope for the project, they gave the client the confidence that everything would be implemented. As the team progressed through the implementation process, however, it was soon realized that the scope was too large. A project rescope was necessary. Such rescoping had to be approved by the client. The client was hesitant and demonstrated concern about rescoping the project – partly because they did not understand the programming challenges facing the team. It is important that "engineers must learn to interact with non-engineers" [8]. When working with people who are unfamiliar with the technical challenges of a project, an important role of an engineering team is to educate the client. As the project progressed, the client learned more, communication was facilitated, and subsequent rescoping of the project received less resistance.

One problem with nearly all design projects in developing communities is funding. Nogis had specific hardware and software requirements. The WHPI did not meet any of these requirements and it was not feasible to use what they had. The team needed to obtain replacements. Obtaining the funding to accomplish this was difficult. Because the WHPI could not contribute significant financial resources to the project, the team looked to other sources for help. The United States Geological Survey donated computers that satisfied the hardware requirements. They received new computers and were looking to get rid of their old ones. Microsoft donated copies of Windows XP Professional and Office XP to install on the computers. Seeking donations from large companies played an important role in the project: without them the project would have failed.

Another problem was that the client's primary language is Spanish. None of the senior design team members were fluent in Spanish. The team received several forms from WHPI to assist in designing the system but many were in Spanish. The end users of the system would also need to be trained in a series of training sessions. Outside help was needed for the team to be able to meet their client's needs. Two translators were brought onto the team. They played several important roles. They were responsible for translating Spanish forms, translating the software's interface and manual to Spanish, and giving the training sessions. The language barrier, a seemingly large challenge for an international project, was more straightforward to resolve than the gap in technical proficiency between client and design team.

Completion and Maintenance of Nogis: Impact of Service-learning on the Design Team

The final presentations for all projects in ENGR 498 occur at Engineering Design Day. On that day, groups presented their projects. Several other groups had experienced problems similar to Nogis and rescoped their projects. The majority of the projects were for industrial sponsors who supported senior design projects primarily to establish contact with students, rather than a strong need for the product output. Nogis, however, was different. The WHPI was relying on the team to produce the system they needed. An incomplete project was not going to work and it was highly unlikely that the project would be continued in the following year's ENGR 498. One of the team members and coauthors of this paper decided to complete the project outside of school. Through recognizing the impact the project would have on the WHPI and the community it serves, he saw the importance for this community-based organization to receive their product. He is currently completing this project as a community service project. If this project were for an industrial sponsor, it is highly unlikely that this connection between engineering and its impact on people would have been so directly experienced by the design team. This behavior demonstrates the benefits of service-learning. Students are able to develop special relationships and understand the importance of being active with the community. A demand for this type of opportunity is present as well [9].

Support will be an issue for the Nogis project once it is complete. With any computer-based system, there is a range of potential problems that can arise. Problems with the database or network could arise. Bugs left unfound in the software could surface. If any of these problems occur, use of the system would halt. A system deployed in a situation like the WHPI is going to require additional thought with respect to these problems. If problems arise, how will they be fixed? There are a few ways to approach these problems. One is to let the customer choose who they want to administer the system and provide additional training for them. The complexity of the system will determine how much additional training is required. Volunteers from Engineers Without Borders have used a similar approach and train members of the community how to operate and maintain systems they install for them. This method has the benefit that it indicates the project is "culturally appropriate and sustainable" [10]. It may be possible to inform the client what technologies are going to be used. It would be the client's responsibility to become knowledgeable in these areas. In Nogis's case, the client could have been told to become familiar with administrating a MySQL server and a Microsoft Windows based network. Another option is to find someone that will donate their skills and time to the organization. Supporting the software developed for a project needs to be addressed as well. A community-based organization is not going to have the resources to fix software problems. Ideally, a member or members of the team who designed and implemented the software should continue to provide support. In the Nogis project, the same member of the team that is completing the project has also decided to address these issues by providing support for all aspects of the system for its lifetime.

Lessons Learned about Integrating Service-learning Projects into a Senior Design Class

Nogis is a representative service-learning project from the interdisciplinary design course at the University of Arizona; three others have been completed in the last two years (representing 21% of all projects in the course during that time). From this experience, we have made several observations about the role of service-learning projects in senior design classes.

Compared to industry-sponsored projects, service-learning projects are not better for everyone or worse for everyone – they are different. In both cases, students get a good opportunity to explore how best to proceed through design. Many of the same tools and concepts, for example brainstorming, decision tools, requirements flow down, and testing, are present in both types of projects. There are, however, differences. As shown with the Nogis project, students working on service-learning projects tend to get more experience with identifying needs of a problem. As a result, service-learning projects frequently have larger design spaces within which to explore and generate ideas. Because the client in service-learning projects usually are not engineers, successful implementation is more reliant on the student team than in an industry project where the client has an engineering background. This reliance can be positive because it forces the students into a real situation: if they do not finish the project, the client may not have anyone else who will.

On the other hand, there are benefits to industry-sponsored projects. Most graduates will go on to work in industrial settings, so working on an industrial project can better prepare them for later employment. Furthermore, the connections established by the students with their industry sponsors frequently leads directly to internships or jobs. While the lack of an engineer as a client has benefits as highlighted for service-learning projects, having an engineer as a client also has benefits. For instance, students working with an experienced engineer are much like apprentices and can get an excellent applied education to complement their schooling.

With benefits from both industry and service-learning projects, a key lesson learned is that offering a mixture of these types of projects is appropriate. Students should have a choice as to which type of project they want to work on. Service-learning projects are not the best fit or every student; nor are industry-sponsored projects.

CLOSURE

Engineering design as a process is an adaptable approach to addressing needs. One of its strengths is its ability to address a wide variety of needs: from a defense contractor to a consumer product company to a non-profit healthcare facility on the border of two countries, the same overall design process can be applied. Throughout this process, a client and a design team educate each other about the needs and the solutions. As differences between a client and a design team grow, the need for each to educate the other grows, too. This is a key lesson learned by the Nogis design team that worked with a client in an international, developing community. A client's background will have a heavy influence on how successful completion of a project is achieved. A client like the WHPI will lack several important resources that a design team will require. It is important that a team seeks to receive these resources by searching for outside help. Moreover, the unique attributes of clients in international, developing communities provide excellent opportunities for engineering students to directly see the impact of their work; such experiences should help students understand the role of engineering in a global context and their social responsibility.

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