



The Peugeot Center Model and Mentoring Explored through a Case Study of the Design and Installation of a Potable Water System in Guatemala with ADICAY

KIRSTEN HEIKKINEN DODSON

AND

DANIELA BAUGH
Lipscomb University
Nashville, TN

AVERY ROLAND
University of Tennessee Health Science Center
Nashville, TN

SARA EDMONDS
University of Alabama at Birmingham
Birmingham, AL

HANNAH PINSON YORK
Monroe Carell Jr. Children's Hospital at Vanderbilt
Nashville, TN

ABSTRACT

At the Peugeot Center for Engineering Service in Developing Communities at Lipscomb University, seventeen years of experience have provided the foundation for a program that creates lasting impact. In comparison to other service learning or humanitarian engineering programs, the Peugeot Center is unique in that it achieves substantial impact on students, communities, and engineering professionals. This paper describes the model and mentoring employed by the Peugeot Center with supporting examples from a recent project. The case study describes a potable water system that was designed by a team of students, a professional engineer, and a partnering organization in Guatemala called ADICAY. Though the professional engineer and ADICAY supported the overall design work, the students supported the project by completing a site survey, designing the piping layout, and leading the onsite construction. Through mentoring from the professional engineer, the students developed skills in project management, teamwork, communication, and ethical decision-making. The professional engineer noted the opportunity to use their engineering skills to serve others as a primary reason for involvement. By partnering with ADICAY, the students learned about



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the complex cultural, social, economic, and environmental impacts of their engineering work. The installed system provides potable water to 113 household taps in a rural Mayan community. A medical clinic held before and after the installation of the water system showed a reduction in water-borne illness diagnoses from 40% to 11%. Additionally, data from the clinic showed a lower rate of water-borne illness diagnoses in Setzimaaj (11%) compared to surrounding communities without potable water (33%). Overall, the success of the project is attributed to significant mentoring as well as the deep trust that was built in these partnerships. Lessons learned and best practices for employing a model similar to the Peugeot Center's are reflected throughout the paper.

Key words: mentoring, service learning, sustainability, humanitarian engineering, case study, human-centered design

BACKGROUND

Through these seventeen years of experience, the Peugeot Center has developed and grown to build a model that serves and impacts engineering students, developing communities, and engineering professionals. This article will provide a brief background of the Peugeot Center model and its theme of mentoring to unveil what makes it unique, effective, and sustainable. A recently completed water project will be presented and analyzed as a case study of the impact and success of the Peugeot Center model.

Statements by the National Academy of Engineering (NAE), the Accreditation Board for Engineering and Technology (ABET), National Science Foundation (NSF), and the American Society of Engineering Education (ASEE) have called for changes to engineering education to better adapt to the rapidly changing world (NAE 2008, 2017, ASEE 2017, ABET 2017, NSF 2014). These calls for change reflect topics like global competency, sustainable design, and ethical decision-making, but these can be difficult to incorporate into traditional engineering courses. Faculty in engineering are tasked with teaching the knowledge and skills to solve complex socio-technical problems like those outlined by the United Nations Sustainable Development Goals (UN 2015). To achieve these lofty objectives, many engineering programs have found success in employing service learning in their courses.

Some programs and organizations go a step further past service learning, where the focus is on student learning, to focus on addressing basic needs in the most marginalized communities. These projects tend to be labeled as humanitarian, development, global, or servant engineering. For simplicity, projects that address basic needs and focus on community impact will be categorized as humanitarian engineering in this paper. As the field has evolved and improved, the line that



differentiates service learning from humanitarian engineering has begun to fade. Service learning programs have begun to shift focus to ensure the impact on the community is as substantial as the impact on students. The following summarizes some of the programs and organizations that utilize service learning or humanitarian engineering and their impacts with the goal of framing the Peugeot Center model.

Seventeen programs are detailed in the 2015 Special Issue of the International Journal for Service Learning in Engineering called 'University Engineering Programs that Impact Communities: Critical Analyses and Reflection' (2015). One outstanding program that reflects these intended impacts is the Engineering Projects in Community Service (EPICS) program developed by Purdue University (Zoltowski and Oakes 2014). Though originating at Purdue, the model has been expanded to more than 30 universities and multiple studies have shown a clear impact of the EPICS program on student development and learning (Oakes et al. 2019, Pierce, Oakes, and Abu-Mulaweh 2019, Zoltowski and Oakes 2014, Huff, Zoltowski, and Oakes 2016). Other commendable programs have benefited from service learning or humanitarian engineering projects with the support of faculty advisors or organizations like Engineers Without Borders (EWB), Engineers for a Sustainable World (ESW), or Engineering World Health (EWH) (Sacco and Knight 2015, Malkin and Calman 2015, Dale et al. 2015, Pinnell et al. 2015, Dean and Bossuyt 2015, Colledge 2015, Bixler et al. 2015, Sandekian, Chinowsky, and Amadei 2015, Ermilio, Clayton, and Kabalan 2015, Bratton 2015, Duff et al. 2015). As with any complex problem, these programs have encountered obstacles along the way including failed partnerships with non-governmental organizations (NGOs), frequent chapter turnover, institutional hurdles that create unnecessary bureaucracy, and a lack of commitment from professionals (Lewis 2015, Suhr et al. 2015, 2013). Additionally, though the benefits of service learning in engineering have been well documented, the community and social impact is less studied. Armstrong et al. examined existing service learning engineering programs and identified 49 factors that may be related to success with respect to social impact (Armstrong, Mattson, and Lewis 2021). Based on a review of projects completed in 2019, the Peugeot Center satisfies nearly all of these with only five found as possible shortcomings of the program. With respect to the challenges typically encountered in service learning or humanitarian engineering programs, the Peugeot Center has built a model that ensures sustainability of the program and success for each project.

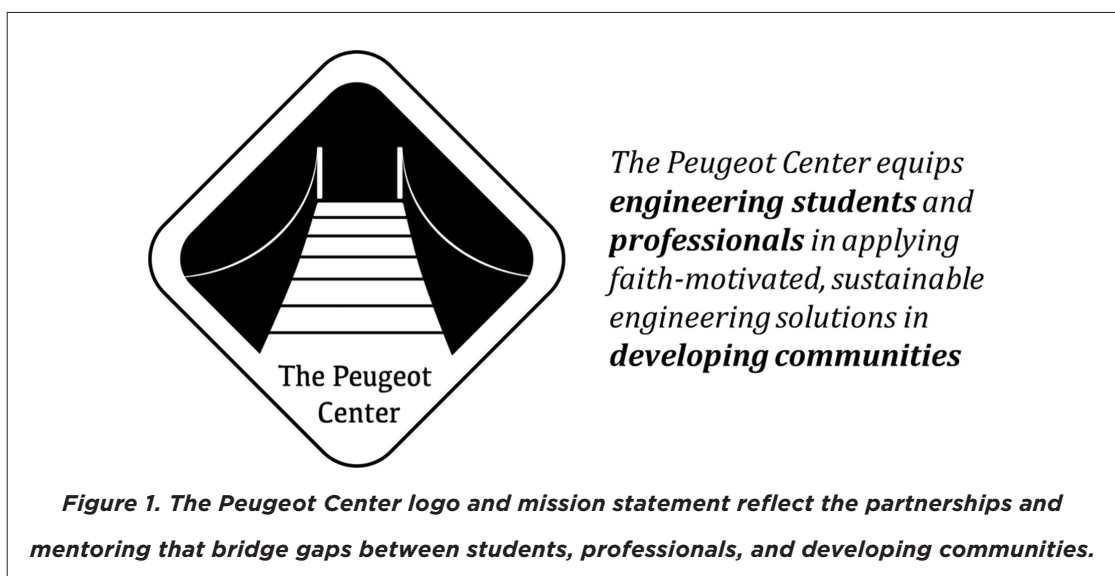
A key factor to the success and sustainability of the Peugeot Center is the significant mentoring that provides a foundation for the model. Mentoring is well-established as transformative and beneficial for training engineers as evidenced by various programs and studies as well as the licensing procedure for the National Council of Examiners for Engineering and Surveying (NCEES) (Wallace and Haines 2004, Pisimisi and Ioannides 2006, Chelberg and Bosman 2019,



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NCEES 2019). While traditional service learning can be described as a teaching and learning exercise, mentoring through service learning goes deeper by encouraging a combined personal and professional relationship toward a communal humanitarian goal. Mullen summarizes the complex field of mentoring and describes three contexts for it: “a personal-professional relationship to an educational process; an organizational, global, and cultural context; and a systemic reform strategy that builds human capacity.” (Mullen and Klimaitis 2021). The mentoring provided through the Peugeot Center model takes on characteristics described in these three contexts. The model also has features similar to the mentoring ecosystem described by Mondisa et al (Mondisa, Packard, and Montgomery 2021) as well as the progressive mentoring detailed by Santora et al (Santora, Mason, and Sheahan 2013). Continued from Mullen, nine types of alternative mentoring are described, six of which are exhibited through the Peugeot Center model including formal, informal, collaborative, group, peer, and cultural (Mullen and Klimaitis 2021). These mentoring types will be referenced throughout the rest of the paper.

While the mentoring structure has not been formalized by the Peugeot Center, it has strengthened the mission and sustainability of the program. As exhibited by the mission statement and logo as seen in Figure 1, the Peugeot Center bridges a gap to serve three distinct groups: engineering students, engineering professionals, and developing communities. The Peugeot Center is one-of-a-kind in its mission to serve and impact all three of these groups through significant mentoring relationships. The impacts on each group is examined at the end of the paper.



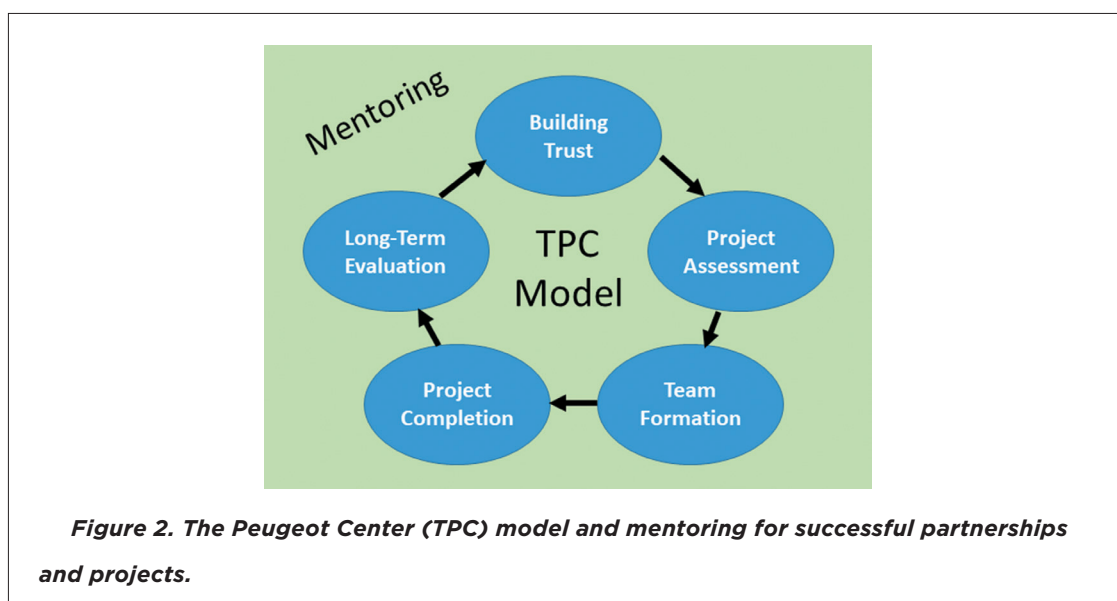


THE PEUGEOT CENTER MODEL

To give a brief history, the Peugeot Center was officially established in 2014 as an entity within Lipscomb University's Raymond B. Jones College of Engineering, but the foundation for the Peugeot Center was paved in 2004. That year, a group of engineering students requested support from the faculty to work on a humanitarian engineering project with a non-profit organization in Honduras. Since then, 150 of the approximately 360 students that have graduated from Lipscomb's engineering program have been involved in at least one project during their college career. Many of these 150 students chose to complete multiple extracurricular projects, and some have continued participation as team leaders or technical mentors after graduation. Over the seventeen-year history of the program, more than 55 projects have been completed impacting an estimated 22,000 people.

The Peugeot Center model as displayed in Figure 2 is vital to the success of the projects and partnerships. Note that the model can be imagined as a cycle, similar to the engineering design process with two important additions. *Building trust* connects the end of a project to the beginning of the next whereas *mentoring* serves in the background to support the process. As the Peugeot Center has iterated upon its own model over the years, building trust and mentoring have become central to ensuring project success, program sustainability, and high levels of impact.

The achievement of long-term sustainability from a programmatic perspective comes from deep investment through mentoring individuals that volunteer with the Peugeot Center from the beginning

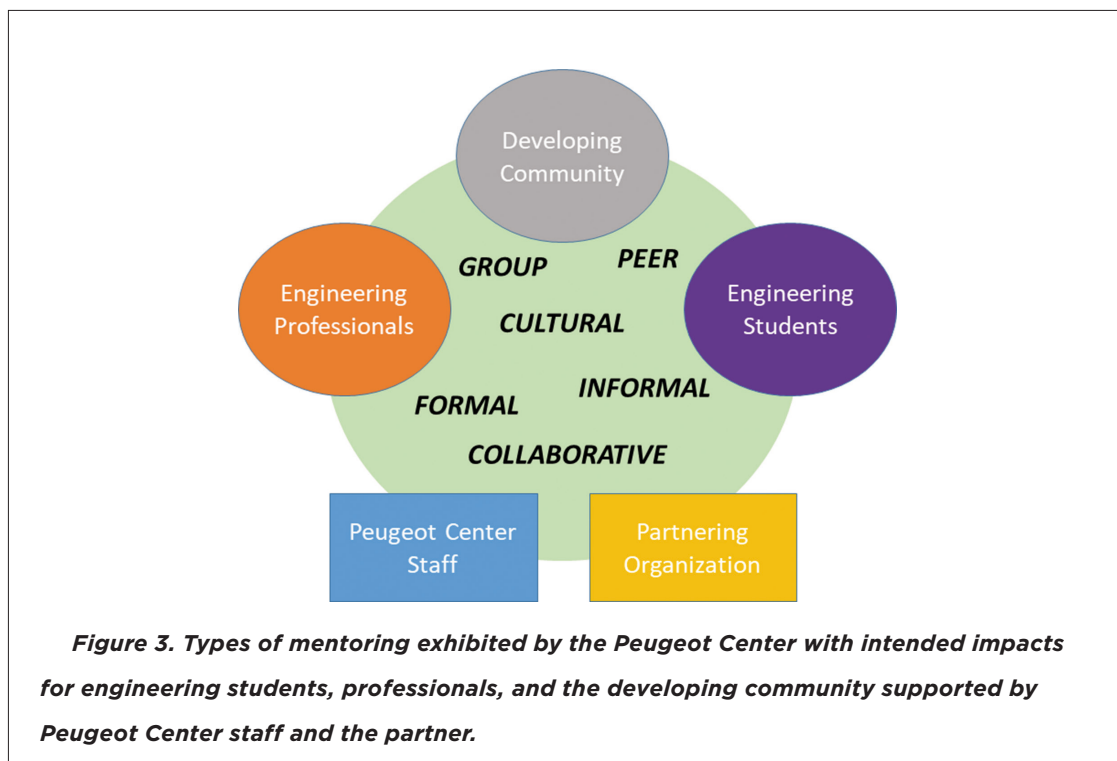




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of their journey. Students are empowered to step into the design and construction aspects of the project with support from the technical mentor while simultaneously being welcomed into fellowship by the team leader. Upon graduating, these students become professionals and are invited to step into those technical mentor and team leader roles. This process creates a heavily invested person with working knowledge of not only the Peugeot Center model, but also with a passion to pass along the mentoring they received to like-minded students. At present, the Peugeot Center has active technical mentors and team leaders that began their journey as students in the engineering college at Lipscomb in 2002. Though the act of mentoring is difficult to define, Vesilind's words ring true to the professionals that are invested in Peugeot Center projects: "Mentoring comes from the heart. Ya gotta love it." (Vesilind 2001).

To describe the mentoring that occurs in the Peugeot Center model, Figure 3 shows the types employed as well as the groups involved. Peugeot Center staff and the partnering organization participate in collaborative mentoring where healthy exchange of feedback and guidance create a level and trusting relationship. Peugeot Center staff formally train and mentor engineering professionals to be effective team leaders and technical mentors. The engineering professionals lead group mentoring for engineering students and cross the lines between personal and professional





relationships through team fellowship and project work. Students peer mentor one another before and during a trip as past participants support new team members as they learn how to function and work on a Peugeot Center team. The students also receive informal mentoring from the partner during design reviews and meals, again combining professional and personal relationships. Cultural mentoring ties all five groups together and is a continual process of learning and growing. Because culture is so complex, engineering professionals, students, and Peugeot Center staff are mentored through unfamiliar traditions and social norms by the partner and developing community. These mentoring relationships are core to the Peugeot Center and provide for clear, direct, and effective guidance and feedback that support project success. The impacts of this mentoring will be described in more detail throughout the remainder of this paper.

TPC MODEL EXAMINED THROUGH A CASE STUDY

The following case study supports description of the Peugeot Center model and details the design and implementation of a potable water system with partnering organization ADICAY.

Building Trust

TPC Model

As potential partners are presented to the Peugeot Center, a vetting process occurs to ensure that the two organizations have common goals and objectives. The vetting occurs in both directions as the Peugeot Center expects to be vetted by the partner to ensure mutuality in the process. Staff at the Peugeot Center visit the partner to examine the organization and its team, specifically, their commitment to serving and empowering their local community. Where the Peugeot Center brings engineering knowledge and skills as well as funding opportunities to the partnership, the partner provides valuable insight to the community as a social and cultural bridge. During these first meetings, mutual goals are examined and the partnership is initiated with low risk, small scope projects. As cycles of trust are built and the partnership deepens and strengthens, the projects can increase in risk and scope. Also examined during the vetting process is the trust that the partnering organization has with the developing community. As locals with an understanding of the culture and social structures in the community, the partnering organization provides cultural mentoring and is able to communicate needs, desires, constraints, and capital that may not be apparent to the Peugeot Center. Because building trust is vital to the success of the program and projects, the Peugeot Center focuses on long-term relationships with partners to maximize effectiveness and impact as supported by literature (Munoz 2015).

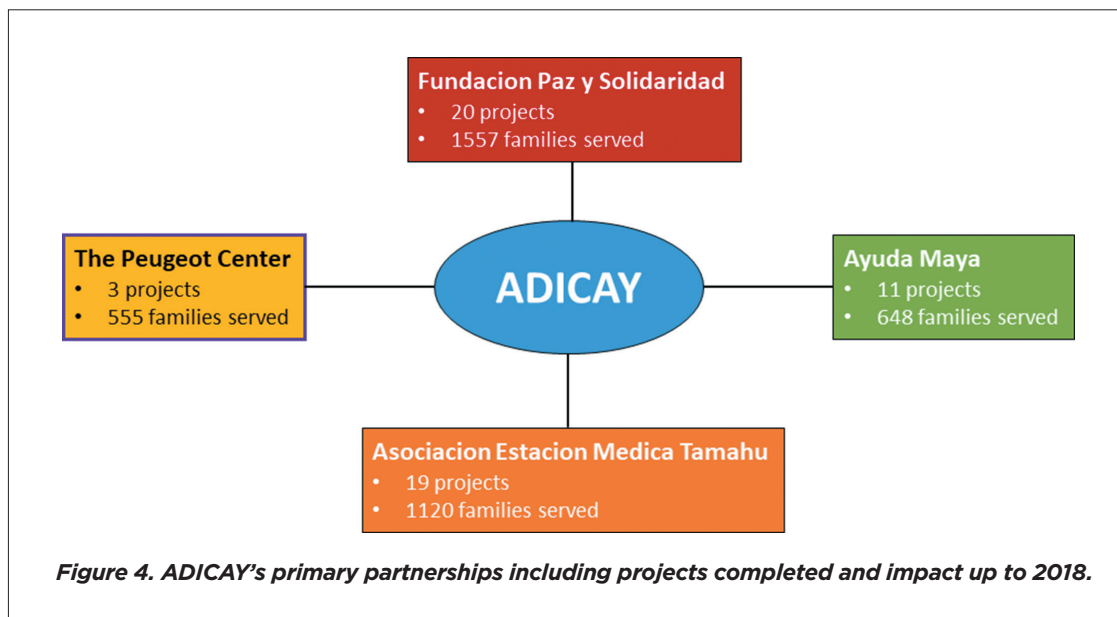


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Case Study

Though the Peugeot Center has found success in supporting a wide variety of teams and projects in numerous locations around the world, the strongest partnership yet has been built with a Mayan organization in Guatemala called ADICAY. ADICAY (the acronym for the formal name: Asociación para el Desarrollo Integral Común Ak' Yuam) is an NGO staffed by 10 native Mayans and based in Coban, Guatemala, that focuses on rural community development. Specifically, ADICAY works in the Alta Verapaz region of Guatemala, an area of the country known by some as 'Sendero de Muerto' or 'corridor of death' due to the high rates of maternal mortality (2019). The causes of this high rate of maternal mortality are attributed to lack of health services, extreme poverty, and lack of education. To address these challenges in the region, ADICAY completes water, sanitation, and hygiene (WASH) projects including potable water systems and latrine installations. Since their inception in 2011, ADICAY has built partnerships with four organizations to become a well-established and successful organization in the Alta Verapaz region. The details of these partnerships and their impact on Mayan communities are summarized in Figure 4 (2018). Based on an assumed average household size of six, ADICAY's impact in this region of Guatemala was estimated at about 23,000 individuals from 2011 to 2018.

The Peugeot Center developed a partnership with ADICAY through a mutual contact in 2014. To begin the vetting process, the Peugeot Center visited ADICAY to discuss mutual goals and examine one another's organizations. Due to ADICAY's existing work and prior partnerships, their impact and commitment to their work serving Mayan communities was clearly documented (as evidenced in Figure 4). In return, ADICAY vetted the Peugeot Center by examining past project reports and





visiting nearby project sites where they found substantial positive impact. Mutual goals and objectives were agreed upon during the meeting including a commitment to serving Mayan communities through WASH projects as well as open and honest lines of communication through a chosen point-of-contact from each organization. After a few smaller projects with low risk and small scope, a foundation of trust was built and larger projects began. Since then, the partnership has grown and flourished and is now thriving and highly impactful.

Note that the partnership extends past the Peugeot Center and ADICAY to include the community. Building trust and a strong partnership with communities can be extremely difficult for organizations foreign to the country and culture. To bridge this gap, ADICAY's cultural and collaborative mentorship to the Peugeot Center is vital to the success of the projects due to the strong trusting relationships they have built with the communities. Because of a common threat of corruption in the region, ADICAY deals directly with community leaders rather than the mayors of nearby cities. In the past, some of the mayors have attempted to take credit for ADICAY projects. In response, ADICAY now installs signs in the communities that detail the funding agency, labor provided by the community, and the partnerships involved in the project completion (Figure 5). This sign provides

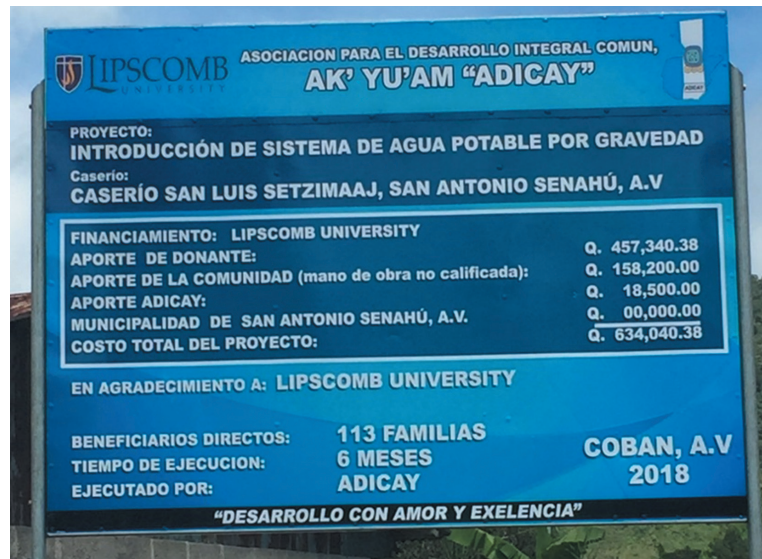


Figure 5. ADICAY installed the sign shown above, which details the contributions of each party, following the completion of the potable water system in Setzimaaj. 'Aporte de donante' refers to donor contribution. 'Aporte de la comunidad' refers to community labor contribution. 'Aporte de ADICAY' refers to ADICAY's contribution. 'Municipalidad de San Antonio Senahu' refers to the nearby city government in Senahu.



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a sense of pride for the community and exhibits not only the partnerships that supported the success but also their own hard work toward completing the project. The trusting relationships that ADICAY is able to build and sustain with the communities provided more concrete evidence of the potential for a strong partnership during the vetting process.

Project Assessment

TPC Model

Project assessment begins when the Peugeot Center receives a request for a project from a vetted partner. An important aspect of approving a project is determining if the scope of the project is appropriate for Peugeot Center teams. The expectation is that a team of students and an engineering professional serving as the technical mentor can fully complete the project in about 1-2 years including a preliminary study, a site survey, design reviews, and implementation. The goal is to select a project where students can utilize their engineering knowledge and skills with mentoring from a professional and complete it before graduating. In some cases, the professional leads the design and delegates tasks to the students; in others, the professional oversees and supports the student-led project. It is important that the projects be complex enough that students are challenged, but not so difficult that the professional cannot delegate tasks to the students. Because engineering professionals are involved in every Peugeot Center team, the projects have higher impact yet higher risk than what students could complete alone. Students receive formal mentoring by the professional who also serves as an expert to reduce risk and approve the final design. This ensures that the completed project will be highly impactful toward addressing the community need while also allowing for student growth and development.

The risk and cost of the project are also taken into consideration when selecting projects. With every project, there is a risk of failure that could arise from lack of funding, poor project development, or miscommunication between partners among other causes. Where possible, the Peugeot Center selects projects where risk and cost are balanced with impact. Large-scale infrastructure projects are frequently chosen as they tend to maximize impact by addressing community-wide critical needs, such as potable water, pedestrian safety, hygiene, or energy. Project costs, such as materials and tools, are typically subsidized to avoid an unmanageable financial burden on the recipients. The partnering organization provides insider knowledge to guide the selection process toward those basic needs that will best support community development. The Peugeot Center staff lean heavily on the expertise of professionals and the partner to examine the risk, cost, and scope of projects. Projects not chosen by the Peugeot Center may be delayed until resources can be allocated to the project or passed on to another organization more suited to the project.

The Peugeot Center also recognizes that students' collegiate careers are fairly short-term in nature which can cause obstacles toward project completion. Expecting students to invest in a long-term extracurricular project requires exemplary commitment by the student to go above and beyond the



typical college degree. In a report on EWB-USA programs in Guatemala, the author comments on the likelihood of chapter turnover (student and professional) as the primary reason for project cancellation (2013). At the Peugeot Center, the short-term nature of college student involvement is accounted for by ensuring the scope for project completion is a maximum of two years. This provides students and professionals with an expectation that their commitment to a project will be fulfilled at the end of two years. Additionally, the two-year commitment ensures that communities are served in a timely manner, which is imperative when designing for basic needs such as clean water and safe travel. Without on-time completion of these projects, the health and safety of the community may be in jeopardy.

Another important aspect of project assessment is ensuring that the project is needed and wanted by the community and willing to be supported by the partnering organization. Every project that is requested requires approval by all three parties involved: the community, the partnering organization, and the Peugeot Center staff. First, a need is documented in the affected community through data, photos, or personal (and confirmable) stories. To ensure the community will take responsibility for the project, they are required to make a request for assistance. This initial request from the community for assistance is an important factor toward long-term ownership of a project. The partnering organization then meets with the community to discuss expectations and helps write a letter of request to send to the Peugeot Center. If any of the parties do not approve the request for any reason (i.e. fear of corruption by the partnering organization or lack of interest by the community), the project is not pursued. Though this typically ends the project cycle, continued conversation can occur to remove fears or doubts such that an approval can move forward.

Case Study

In 2012, the Guatemalan government ceased the funding of a local health clinic in the rural Mayan community of Setzimaaj leaving the area with no access to healthcare. In response, a team of Lipscomb students and medical and dental professionals traveled to Setzimaaj in 2013 to host an annual one-week health clinic. The clinic provides curative relief services alongside local health promoters for Setzimaaj and the 12 surrounding communities where they typically receive about 400 patients during the week. The Lipscomb teams saw a need for clean water due to frequent high-levels of water-borne illnesses, which are primarily caused by consumption of contaminated water. Symptoms like dehydration, stomach cramping, diarrhea, and blood in the stool were common complaints of the patients.

Because a documented need was present, the Lipscomb team reached out to the Peugeot Center to investigate the possibility of installing potable water systems. In May 2017, ADICAY and the Peugeot Center sent a small team to visit the affected communities, examine existing water sources (most of which were contaminated based on lab testing), and discuss possible solutions. During these visits, ADICAY mentored the communities about the level of trust required and the responsibilities that come



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with a water system like paying fees, improved water hygiene, and assembling a water committee. Setzimaaj was the first community to write a formal request for a potable water system as shown in Figure 6. Included in the contract is recognition that every household that requests a tap must provide a certain amount of labor, which is tracked by the community leaders to ensure honesty and fairness.

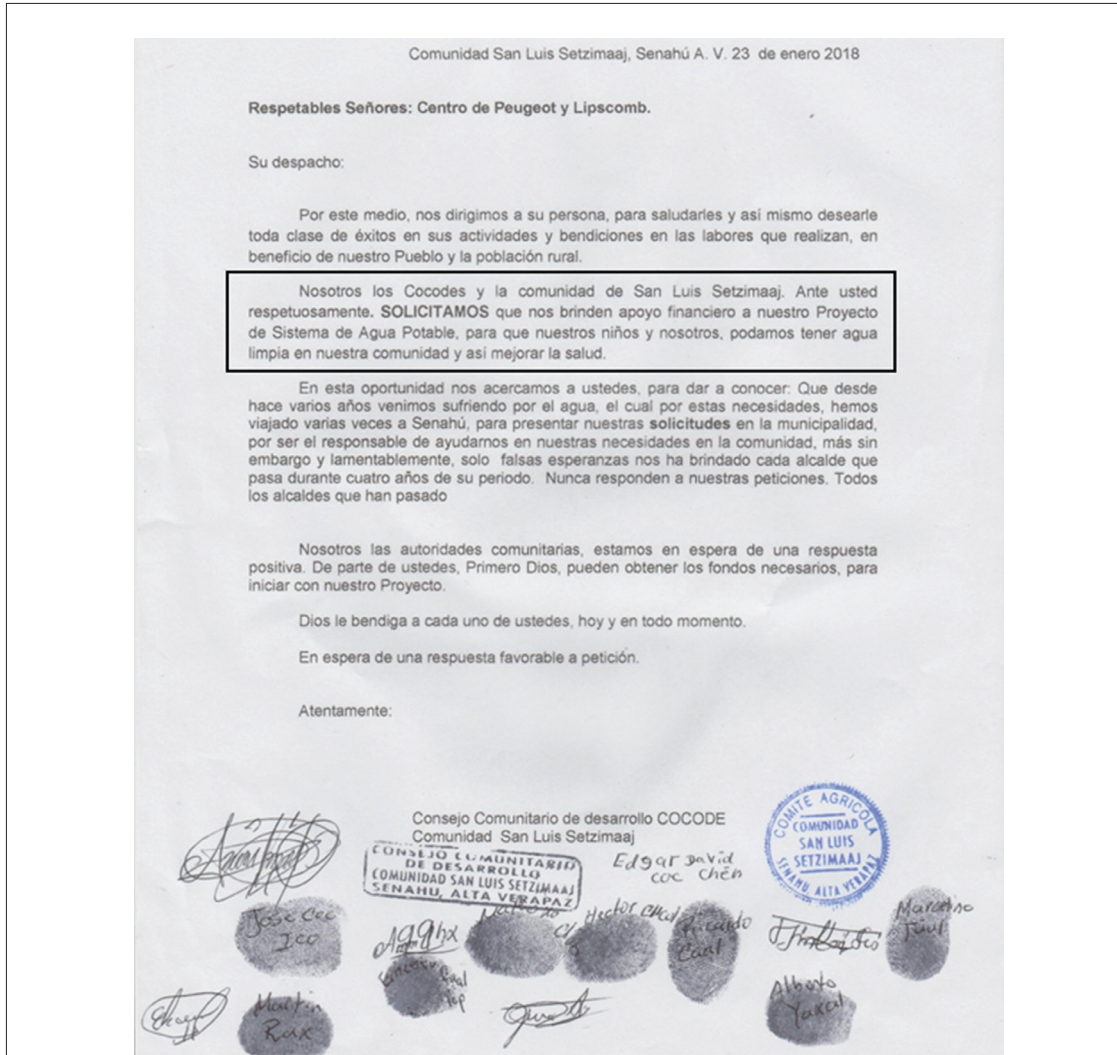


Figure 6. The contract completed by Setzimaaj community leaders as a request for the completion of a potable water system. The boxed section translated: “We the Cocodes (leaders of the community) and the community of San Luis Setzimaaj. Before you respectfully. We request that you provide financial support to our Potable Water System Project, so that we and our children can have clean water in our community and thus improve health.” The signatures at the bottom include the Cocodes, Agriculture Committee, and Development Committee of Setzimaaj.



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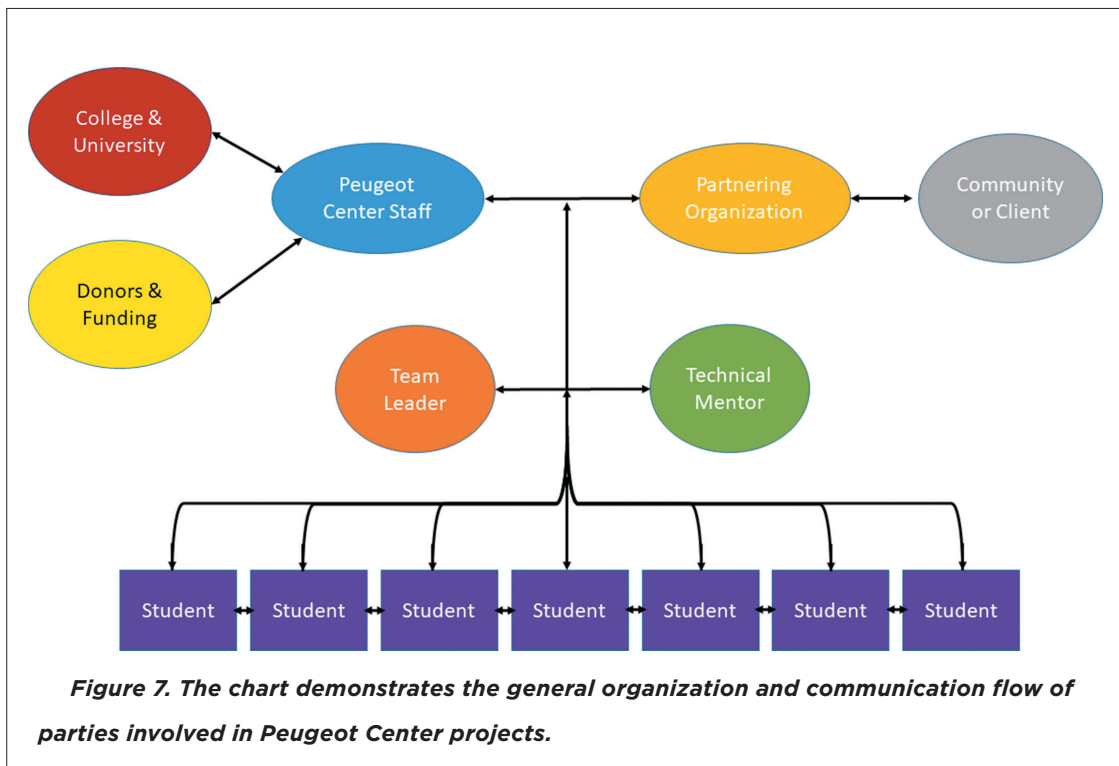
Through multiple discussions during the summer of 2017, the Peugeot Center and ADICAY approved the project for completion. Based on the scope, feasibility, and cost, a gravity-fed catchment and distribution potable water system was selected as the basis of design. The catchment at the water source and transmission of the water to a distribution tank above the community was assigned to ADICAY for design while the distribution of the water throughout the community was assigned to the Peugeot Center.

Team Formation

TPC Model

Once a project is approved, a team is assembled by Peugeot Center staff containing engineering students (team members) and professionals who serve as the technical mentor or as the team leader. Figure 7 below describes the general organization of the Peugeot Center staff and teams as well as communication between associated parties.

The roles and responsibilities of the team leader include scheduling, budgeting, coordinating travel and lodging arrangements, organizing meetings, cultural preparation, and strengthening team morale. Though it is beneficial to have skills in the appropriate field for the project, it is not a requirement for the team leader but is required for the technical mentor. The roles





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and responsibilities of the technical mentor include evaluating project goals, assigning tasks to students, verifying the design, and teaching students new skills and concepts where necessary for project completion. Peugeot Center projects must have a separate team leader and technical mentor as the responsibilities of these two roles are too much for a single person to handle. Though in separate roles, the responsibilities of the team leader and technical mentor come together to provide direct management of the project and leadership for the team. Additionally, both roles provide significant mentoring for the students.

The use of technical mentors and team leaders in Peugeot Center teams provides formal mentoring to students through a real-world project and team experience. Technical mentors pass on their own knowledge and skills to students to ensure effective project completion in a timely manner. Lack of progress or ineffective project completion can damage the foundation of trust with a partnering organization and community. Team leaders on the other hand ensure that the team is prepared to function well together toward the central goal of serving the community. The qualities required of these two leaders include deep commitment to the team and project, good communication across groups, and the ability to manage obstacles that inevitably arise with any complex problem. The leaders then pass on and encourage these traits in the students through formal mentoring to create a more well-rounded and career-ready engineering student. Thus, mentoring from the leaders is a significant part of Peugeot Center projects and student impact.

Likewise, the engineering professionals that volunteer their time also gain valuable mentorship from the Peugeot Center staff and other seasoned team leaders and technical mentors. Because professional engineers work a full-time job and typically have other personal responsibilities, the valuable time and effort they devote to the program is usually limited. To support and streamline these roles, the Peugeot Center staff host training sessions to ensure that team leaders and technical mentors understand their roles and responsibilities. During this training, the professionals learn how to integrate students into the project and receive guidance on best practices for mentoring students. To minimize the amount of preparation work required from these volunteers, the Peugeot Center provides tangible resources, such as team meeting schedules and outlines, presentations for cross-cultural awareness, and incident management materials. In addition, inexperienced technical mentors and team leaders receive guidance and instruction from seasoned professionals that are familiar with the responsibilities required in these roles. As new professionals express interest in getting involved with the Peugeot Center, they are first trained by the Peugeot Center staff and then paired with experienced leaders on a project to serve as a 'team-leader-in-training'. Throughout the project, the experienced leaders mentor the new leaders through the process of mentoring students, working with the partnering organization, and completing the project effectively. This mentoring relationship between new and experienced leaders has been a significant factor in drawing young professionals to participate in Peugeot Center projects.



Case Study

Two sets of students, one team leader, one technical mentor, and one team-leader-in-training participated in the Peugeot Center team that completed the water system in Setzimaaj. The first set of students was comprised of five senior-level mechanical and civil engineering students. The second set of students was comprised of six mechanical and civil engineering students ranging from freshmen to seniors in the college. The first set performed a site survey in November 2017 whereas the second set participated in the installation of the distribution system in March 2018. The team leader, technical mentor, and team-leader-in-training participated in both the survey and installation. Only one student, a senior-level civil engineering student, participated in both groups. The technical mentor was chosen for the team based on his occupation as a professional water and wastewater engineer and his experience with designing and installing gravity-fed water distribution systems in Guatemala. The team leader was a faculty member in the engineering college who is the primary point-of-contact with ADICAY and had led other Peugeot Center teams in the past. The team-leader-in-training was a recent civil engineering graduate from Lipscomb who had participated in several Peugeot Center projects as a student. Prior to meeting with the students, these three leaders were mentored by Peugeot Center staff through a training session in October 2017 where they discussed project and team objectives as well as best practices. The leaders were also provided with materials like existing project information, budgeting and scheduling documents, and team development guidance.

Project Completion

TPC Model

After team formation, the Peugeot Center staff facilitate communication between the team leader, technical mentor, and partnering organization. From this point, the team leader and technical mentor are responsible for progress toward project completion, but are free to lean on Peugeot Center staff for continued mentoring as needed. Because each project and community are so unique, there is no blueprint for teams on how to complete their project. The Peugeot Center team, especially the team leaders and technical mentors, must be ready to adapt to challenges along the way.

During project completion, students are provided with opportunities to experience real-world project and team management alongside valuable apprenticeship from technical mentors and team leaders. In addition to working closely with the professionals on the project, students learn about cultural engagement, community development, environmental impacts, and sustainable design techniques. Because the projects require hands-on implementation alongside local community members as well as onsite design adjustments, there exists a natural combination of technical and cultural mentoring. Students are required to utilize ethical decision-making and must critically think about long-term success and non-technical factors when addressing the needs of a community due to the real risks and consequences of



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the project. These are important skills and concepts for students to learn, but cannot easily be taught in a classroom or on paper and thus are taught through mentoring and a real-world project experience.

Case Study

With the teams formed and project approved, ADICAY and the Peugeot Center team began work on the project. Throughout the project, students participated in the design, analysis, and construction in various ways. Regular virtual meetings between ADICAY and the Peugeot Center team allowed for design reviews, project feedback, and updates on progress. As a first step, the two groups surveyed the water source, transmission line, distribution paths, and locations of homes in November 2017. During the site survey, the students worked alongside ADICAY and the technical mentor to accurately map the water source and community. While on-site, the students also participated in community meetings where ADICAY discussed the project with community members and next steps for the work. As a trusted organization with the community, the students experienced first-hand the exemplary teamwork skills, project management, and communication exhibited by ADICAY in those meetings. While ADICAY was formally mentoring the community during these meetings, the students also received informal mentoring on community development concepts.

After the survey was complete, students used EPANET, a water system modeling software from the United States Environmental Protection Agency, to design the distribution system. Based on the design, students completed a bill of materials and construction plan with continued guidance from the technical mentor. The team regularly met with ADICAY to review and adjust the design. ADICAY delivered unique mentoring to the students by combining technical knowledge with cultural and social factors that technical mentors cannot easily provide. For example, the team originally designed a looping distribution system to provide redundancy in case one side of the system failed due to a breakage in the pipe. During a design review meeting, ADICAY advised against the looping distribution and instead suggested a branching system. With a looping system, a new household desiring a tap could cut into a service line without the consent or knowledge of the community. With a branching system, the breakage in the line would be recognized as a breach and could be addressed by the community and ADICAY. In this way, ADICAY provided valuable insight and mentoring on the complex socio-technical design factors of the system.

With this feedback, the Peugeot Center team re-designed the distribution system to branch to 113 homes in Setzimaaj (Figure 8) while ADICAY completed the structural design of the catchment and distribution tanks. After approval from ADICAY, the Setzimaaj community and the Peugeot Center, the distribution system was built in March 2018. The students participating in the installation gained experience that was unparalleled in their academic career. With guidance from the technical mentor and ADICAY, the students worked alongside community members to construct the system.

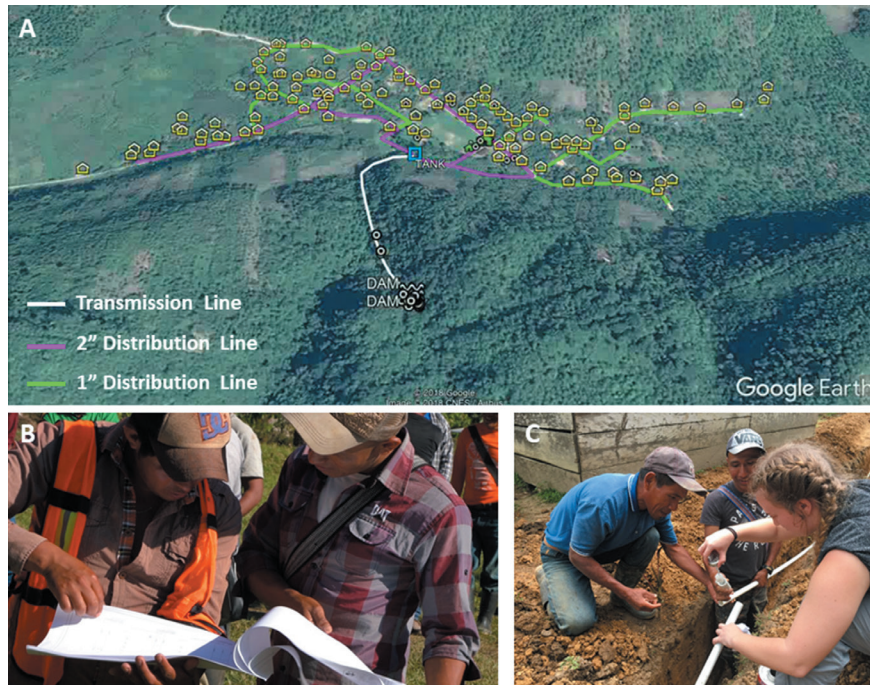


Figure 8. A: The layout of the branching water system. B: An ADICAY staff member instructing a community member on the design. C: A student working alongside community members to install piping.

The students experienced a combination of cultural and technical mentoring as they worked hand-in-hand with the community to overcome design challenges and language barriers. This ability to pivot and adjust onsite in an unfamiliar environment provided a distinctive yet formative experience for students that will be highly beneficial in their future careers.

As an organization of Mayan Guatemalans who speak the native language of the communities, ADICAY is able to mentor communities through team building exercises that advocate for working together and supporting each other toward common goals. These activities are meant to improve honesty, trust, communication, and respect between ADICAY and the community and within the community members. Because of ADICAY's position as a trusted and respected organization, community members are willing to listen and grow from this instruction. Figure 9 shows an ADICAY staff member mentoring Setzimaaj community members through a team building exercise in preparation for the installation of the distribution system.

Following the completion of the distribution system, ADICAY and Setzimaaj community members completed the catchment system and distribution tank in May 2018. Though the Peugeot Center



Figure 9. In an orange vest, Samuel Cuc, an ADICAY staff member, instructs community leaders through a team building exercise involving a tug of war game.

team was not present for this final step, there was consistent communication to ensure the project was completed successfully.

Long-Term Evaluation

TPC Model

Due to the two-year limitation on project scope, long-term evaluation and monitoring of the project is planned for by Peugeot Center teams, but then carried out by the Peugeot Center staff or partnering organizations over time. Again, this step of the process is highly individualized for each project and community but may include a variety of measures. Continued site visits are common as well as basic assessments like lab testing of water quality, visual review of bridge joints, and measurements from solar panels. Regular meetings with the partner and communities ensure that the completed projects continue to function as intended and that any remaining issues can be resolved. Most engineering projects have long-term effects that encompass complex socio-technical factors that impact business, education, environment, and health in the community. Evaluation of these impacts are used by the Peugeot Center to improve future projects while monitoring of the projects allows for maintenance, repairs, or re-design as needed.

Case Study

Prior to the installation of the distribution system in March 2018, plans to measure the health impacts in the Setzimaaj community had already begun to assess the project. A group of biology, pre-med, and nursing students met with the Peugeot Center team to determine what metrics would



best evaluate success. Through these discussions, the students decided to utilize the triage cards from the medical and dental clinics to examine if there were changes in the rate of water-borne illnesses before and after installation as well as compared to other communities who lack access to potable water. The results from these plans and the analysis of the data collected is detailed in the section on community impacts later in this paper.

For future evaluation of health metrics, one of these students involved recognized the need to improve the triage cards so that analyzing the data was simpler. For years, the medical and dental clinics used blank index cards to record vital signs, patient history, doctor’s notes and diagnoses, and any treatment. Recording accurate data from the mess of random scribbles was difficult and cumbersome. In preparation for the March 2019 clinic, the student designed new triage cards for both the medical and dental clinics as shown in Figure 10.

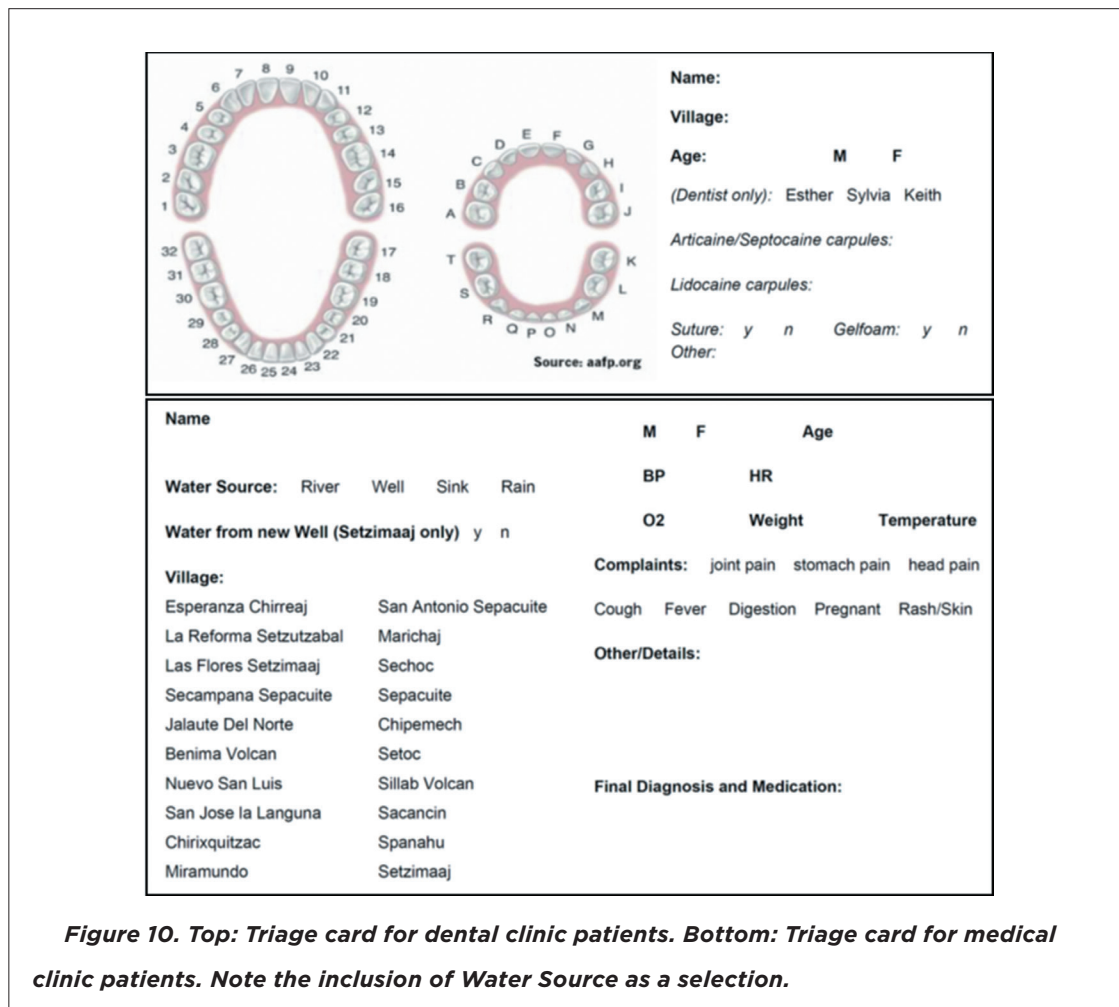


Figure 10. Top: Triage card for dental clinic patients. Bottom: Triage card for medical clinic patients. Note the inclusion of Water Source as a selection.



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These triage cards will be used for future Peugeot Center projects in conjunction with health clinics to better evaluate health impacts of potable water systems.

As a basic necessity, access to safe drinking water can have an impact on the community outside public health. In a meeting with community leaders in January 2019, the Peugeot Center and ADICAY asked if they had seen changes in the community since the water system was completed. Many of them referenced a reduction in illnesses like diarrhea and blood in the stool, but the community leaders also noticed a large increase in school attendance by the children. This increase was perceived to be connected to the reduction in water-borne illnesses in the children that had previously kept the children from attending school. Though it is difficult for the Peugeot Center or ADICAY to accurately record school attendance in the rural community, this indicator shows promise for long-term impact as education is directly linked to prosperity of a community. It is possible that a stronger partnership with local teachers and parents could provide another way to measure the impact of these community projects.

Another significant factor tied to sustainability and long-term impact of community development projects is the capability of the community to support the system after installation. Here, the partnership and mentoring between the two organizations and the community are vital to complete this transition effectively. As a skilled community organizer, ADICAY works with the community to create a water committee of about 8-10 people for every system implemented. The committee and water system essentially act as a utility district. The committees are trained on how to collect monthly fees from each household and how use those to repair the system when needed. As of January 2019, the water committee had collected 1,800 Quetzales (Guatemalan currency) from the monthly fees (5 Quetzales/family) in preparation of any needed repairs and maintenance. More recently, the water committee reported a fund of about 16,000 Quetzales in August 2021. For major repairs or questions, ADICAY serves as the primary contact for the water committee. In addition to the water committee, ADICAY works with the community to support the installation of latrines at each home as well as enlisting volunteers to support beautification and hygiene efforts. ADICAY regularly meets with the water committees in every community to check on financial stability, system maintenance plans, and overall success of the project.

In summary, there exists a variety of opportunities for long-term impact analysis. In Setzimaaj, school attendance, stability of the water committee, and continued improvements to health provide short-term indicators of impact. As these impacts progress and expand over time, higher literacy rates should follow as well as more economic opportunity and more students seeking continued education past primary school. With more communities following Setzimaaj's lead, trusting relationships will be built between communities providing for regional support of one another. As the regional society grows stronger, the rate of development has the potential to increase and continue to



expand outward and upward. With this end in mind, the Peugeot Center and ADICAY have a mutual objective of preparing the communities for a point at which the organizations and their partnership will no longer be needed for continued sustainable development in the region.

Looking ahead to future projects through the partnership described here, the Peugeot Center and ADICAY hope to continue evaluation and monitoring with regard to impact. ADICAY and the Peugeot Center are committed to the long-term success of Setzimaaj and the surrounding communities, not just water projects. Both parties also recognize that sustainability must include social, cultural, and economic effects in addition to the longevity of an engineering project. With this in mind, current initiatives include community building, improved education, and continued medical and dental clinics, including training of health promoters. Long-term initiatives will include investing in small businesses, STEM education, and access to mental health and family services to address addiction, social services, and empowerment of women. As primarily engineering-based organizations, the partnership between ADICAY and the Peugeot Center will be required to grow to include specialists in education, business, and human services in addition to a variety of others. As new partnerships are developed, a wider range of opportunities for evaluation and monitoring will be available and utilized. In the future, outside partnerships will be utilized to perform thorough and long-term evaluations that cover a broad range of assessments including health, education, economy, and society.

To continue building trust and complete the cycle of the Peugeot Center model, ADICAY agreed to serve as an outside evaluator to past Peugeot Center projects, specifically community water systems. ADICAY performed the evaluations and supplied a report to the Peugeot Center in 2020 that details areas of improvement and further community needs. The Peugeot Center believes this critique will provide new avenues for growth and a stronger relationship with ADICAY and communities. Both organizations recognize the imperative to assess long-term outcomes and believe this begins with a trusting relationship that can build and learn from each other.

As the Peugeot Center continues to grow, the foundation of trust formed from partnerships sustains the program. Truly, the model has been built and refined for sustainable expansion. Advancement of the engineering college at Lipscomb will demand the development of relationships with more partnering organizations to support more projects and student involvement. Since 2004, the Peugeot Center has built numerous lasting and trusting relationships with seven unique organizations around the world. On average, the Peugeot Center equips about 60 students and 15 professionals each year to serve on teams to partner with these organizations. With growing partnerships and increasing requests for projects, the need for improved mentoring follows to ensure the program's success and continued impact. The Peugeot Center recognizes the need for formalized mentor training and is already working to create more structure in the program based on existing literature (Stelter, Kupersmidt, and Stump 2021).



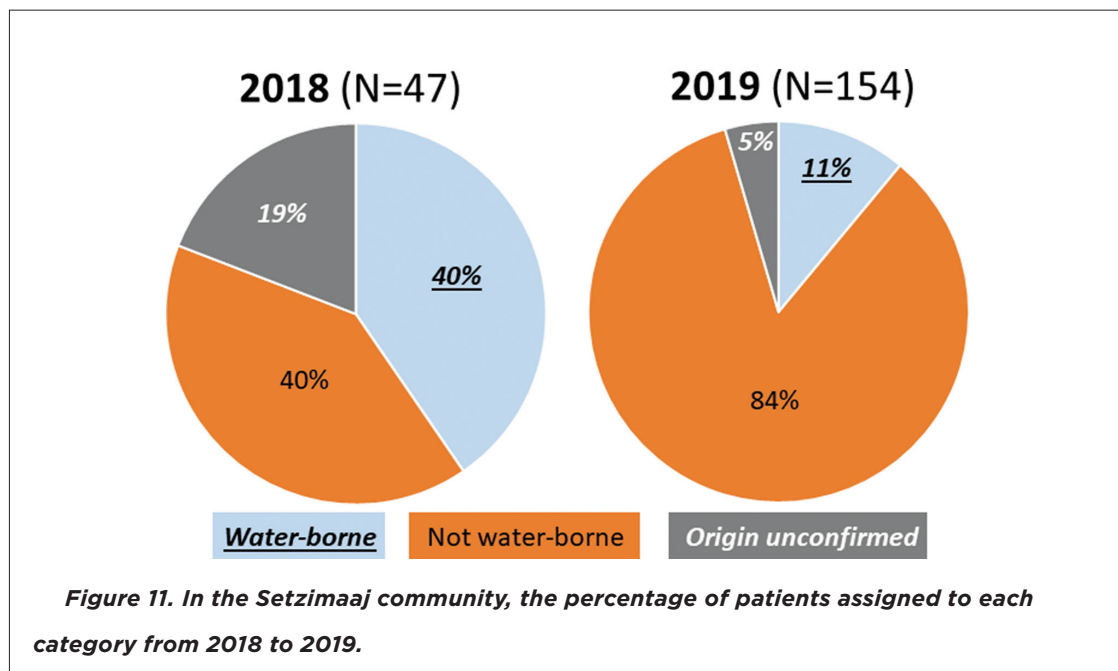
IMPACTS ON STUDENTS, COMMUNITY, AND ENGINEERING PROFESSIONALS

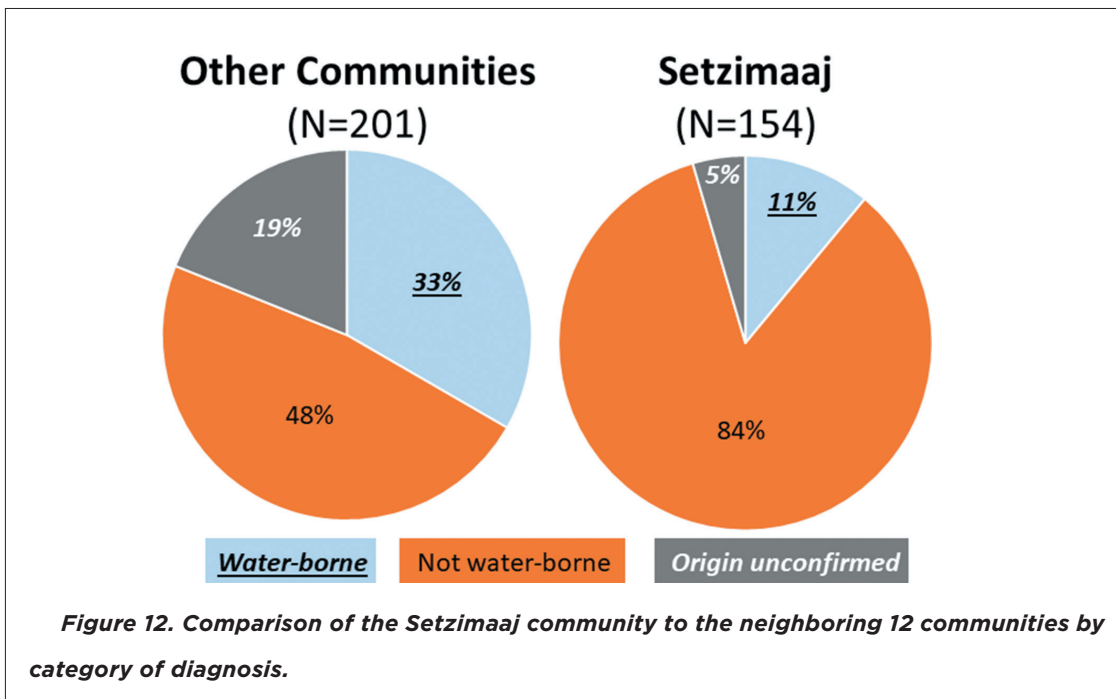
The following sections detail the impacts of the Peugeot Center model and mentoring on the three constituencies of the project: engineering students, professionals, and the community.

Impact on Community

As an immediate indicator of impact on the Setzimaaj community, data from medical clinics was recorded in March 2019 and compared to March 2018. A variety of diagnoses were recorded based on notes from triage cards, then sorted into three primary categories: water-borne illness, not a water-borne illness, and origin of illness not confirmed. Figure 11 shows the percentage of patients from Setzimaaj as sorted by the three categories above. Note the sizable decrease in water-borne illness diagnoses from 2018 to 2019. The primary cause of this drastic decrease is attributed to the potable water system that was installed in the community. The 11% of water-borne illnesses remaining in Setzimaaj are likely linked to other infection routes including consumption of contaminated food or through direct physical contact with a pathogen. Also of note is the significant increase in patients from Setzimaaj seen at the medical clinic from 47 to 154 from 2018 to 2019. This increase may be due to the deeper level of trust built with the community through implementation of the potable water system.

Although there was a clear decrease in water-borne illness diagnoses in Setzimaaj from 2018 to 2019, there is a corresponding increase in non-water-borne illness diagnoses. This could be linked to





the increase in patients due to greater trust toward Lipscomb and the Peugeot Center as described by ADICAY. Patients are more likely to utilize healthcare services when they feel comfortable and confident in the care provided. Though availability of safe drinking water clearly improved some symptoms, other health issues unrelated to water-borne pathogens still remain. Future initiatives by the Peugeot Center and ADICAY as well as the medical and dental clinics hope to address these remaining health challenges. To further support these claims, Figure 12 compares Setzimaaj to the surrounding communities, none of which had reliable access to potable drinking water at the time of the 2019 clinic. As shown, the rate of water-borne illness in the surrounding communities is three times higher than that in Setzimaaj.

As noted before, though the water system was installed in Setzimaaj, the surrounding communities visit the annual health clinic based in Setzimaaj. The timing of the annual clinic was a significant factor in determining the construction plan for the system in Setzimaaj. Though many of the communities have begun to trust the doctors in the clinics, skepticism about implementing a water system in their community still existed due to experience with corrupt local leaders. In March 2018, as the other communities arrived to the clinic, they saw community members from Setzimaaj working alongside ADICAY staff and the Peugeot Center team throughout the community toward building a potable water system. By scheduling the construction during the clinics, ADICAY and the Peugeot Center hoped to spark interest in other communities to request assistance with water systems. Since then,



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four communities have made formal requests to ADICAY for potable water systems with the second community installation completed in 2019 in La Reforma and the third in Los Limones in 2021. More recently, a group of 3 communities made a formal request to ADICAY for their services after a previous water system failed during heavy flooding after Hurricanes Eta and Iota in 2021. The community leaders explained during a meeting with ADICAY and Peugeot Center representatives that they made the request because they saw the benefits of the water systems in neighboring communities including improved health, higher school attendance, and the fact that the systems survived the heavy flooding. This expanded impact to other communities from the first water system installation in Setzimaaj further confirms the success of the ADICAY-Peugeot Center partnership.

Impacts on Engineering Students and Professionals

Because student impacts have been extensively studied with respect to service learning and are generally positive, these are not regularly measured by the Peugeot Center. Instead, the focus is on community impact with the expectation that students will receive benefits from the mentoring through the real-world project experience. Of course, this provides potential for the program to grow to measure direct impacts of student involvement in Peugeot Center projects. An author of this paper is currently performing mixed methods research related to student impacts due to involvement in humanitarian engineering under an NSF-funded grant with results expected in 2022 (Dodson et al. 2021). One simple indirect indicator of the positive impacts on engineering students is the number of students who have been involved with Peugeot Center projects after graduation and have become technical mentors or team leaders. Two students that participated in the Setzimaaj water project are currently in training to lead future teams because of their involvement in this project. This ability to recruit recent alumni to become leaders provides sustainability for the Peugeot Center model. Because these students have experienced mentoring, they tend to be more prepared to serve as mentors as well.

Most professionals are drawn to the work of the Peugeot Center as it provides a purposeful and intentional outlet to serve and create positive impact that they may feel is lacking in their typical jobs. Many of the benefits offered to students are echoed for recent graduates that are new to the industry through this mentorship. Generally, companies do not allow entry-level engineers a high amount of project responsibility in the workplace. Mentoring from experienced professionals on Peugeot Center projects enables young professionals as team-leaders-in-training to increase their experience, preparing them to excel more rapidly in their career. In this way, the Peugeot Center fosters professional networking by creating a platform for forming genuine connections in the field. Frequently, the connections formed have led to employment offers for the students and young engineers while also expanding the pool of qualified applicants for professionals seeking to hire.



Alternatively, the mentoring and project work within Peugeot Center projects provides significant professional development opportunities for young engineers. Over 40 states, including Tennessee, require continuing education via a certain number of Professional Development Hours (PDH) for an individual to maintain professional engineering licensure. In 2017, The Peugeot Center confirmed with the Tennessee State Board of Architectural and Engineering Examiners that the roles served by the technical mentors and team leaders on Peugeot Center teams qualify as an acceptable form of continuing education (2017). In the past, some companies have even approved professional development credit toward career goals in the workplace for the time that these leaders devote to a project. Incentives like these are just one of the many reasons the Peugeot Center is able to retain professional involvement in projects thus improving sustainability of the program itself. The following quotes are from professionals who have participated in Peugeot Center teams:

- *Why did you get involved in the Peugeot Center?*

"I was involved in the Peugeot Center's work while I was a student. Those experiences as a student profoundly impacted my life at the time and still do, more than 10 years later. I want to help provide similar opportunities to current students to have transformative experiences."

- *What benefits do you receive from your involvement with the Peugeot Center?*

"An incredible sense of personal and professional satisfaction. Another benefit is the ability to work in cross-cultural settings that help shape my worldview and also impacts how I approach my profession. I also benefit because being involved with the Center allows me the ability to interact with engineering students that will be entering my profession."

- *Why have you continued your involvement with the Peugeot Center?*

"It is among the richest opportunities for service that I have encountered in my career."

From these testimonials, it is clear that the Peugeot Center bridges a gap for professionals to connect their engineering skills to serve developing communities as well as an opportunity to participate in intentional mentoring relationships.

CONCLUSIONS AND LESSONS LEARNED

Through these endeavors, the Peugeot Center has encountered and overcome several obstacles, yielding lessons to consider. As described throughout the paper, building trust and incorporating mentoring have proved to be supportive to the Peugeot Center's service to students, professionals, and communities. While meaningful student impact can be a priority, service learning and humanitarian engineering programs must also focus on significant community impact by choosing projects based on their scale and potential for long-term positive results. Due to the legitimate risks and consequences associated



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with these projects, professionals are vital to the project and provide much needed guidance and mentoring for the students to ensure project success. Simply finding a committed professional to mentor students and lead a project can be one of the biggest constraints. Recruiting professionals may prove more challenging than sustaining their involvement though. Once a professional has supported a project and seen the value of their work and mentoring firsthand, they will likely request future participation.

From the partnership that has developed between the Peugeot Center and ADICAY, a few lessons can be gleaned regarding successful collaboration. In order for a partnership to truly flourish, communication and relationship building are key. Communication needs to be honest, frequent, and clear while relationship building provides a foundation of trust toward mutual goals and objectives. Additionally, communities must be heavily involved in the design process to ensure ownership of the project. Community input and feedback must be valued and encouraged in order for the project to be truly effective. Though the relationships built may be mostly professional, adding in a personal side will improve the mentoring that occurs. Even something as simple as enjoying regular meals together can create a more positive impact to those involved.

To summarize, the overall objective of the Peugeot Center is to connect students with professional engineers and partnering organizations to complete engineering projects that address critical needs for developing communities. The Peugeot Center model has grown and evolved by learning lessons from other sources and experiences (Collier 2007, Moyo 2009, Birzer and Hamilton 2019, Riley 2007) but holds hope that any future missteps will be seen as 'productive failures' and learning opportunities (Arshad-Ayaz, Naseem, and Mohamad 2020). Readers and practitioners are encouraged to review the recommendations provided here but also investigate other sources to build a strong, sustainable, and highly impactful program.

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AUTHORS



Kirsten Heikkinen Dodson (pronouns: she/her) is an Assistant Professor of Mechanical Engineering in the Raymond B. Jones College of Engineering at Lipscomb University. She earned her B.S. in Mechanical Engineering from Lipscomb University and her Ph.D. from Vanderbilt University before returning to her alma mater. Her research interests focus on the connections between humanitarian engineering, engineering education, and equity and inclusion topics. Dr. Kirsten Dodson is the corresponding author of this work. Email: kirsten.dodson@lipscomb.edu.



Daniela Baugh is a Lipscomb University Civil and Environmental Engineering graduate that now works as the Director of Operations for the Peugeot Center for Engineering Service. Before joining the Peugeot Center, she worked for 4 years as a consultant in stormwater modeling and land development. Since her first engineering mission trip in 2013, she has participated on 9 projects, and through them has had the opportunity to work on land surveys, pedestrian bridges, water distribution systems, and masonry stoves.



Avery Roland (pronouns: she/her) is a second year medical student at the University of Tennessee Health Science Center. At the time of this work, she was at Lipscomb University pursuing her B.S. in Molecular Biology. Her current research focus is global and community health through assessment of trauma care systems.



Sara Edmonds (pronouns: she/her) is currently a PhD trainee at University of Alabama at Birmingham in the Department of Microbiology. At the time of this work, she was at Lipscomb University pursuing a B.S. in Molecular Biology and a M.S. in Biomolecular Science. Her research interests are now focused on host-microbe and polymicrobial interactions. She is still very passionate about giving back to her community through science.



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Hannah Pinson York is a Registered Nurse in the Pediatric Post-Anesthesia Care Unit at the Monroe Carell Jr. Children's Hospital at Vanderbilt. At the time of this work, she was at Lipscomb University pursuing her B.S. in Nursing. Upon graduation, she spent one year working in the Medical/COVID Intensive Care Unit at Vanderbilt University Medical Center before transferring to the Children's Hospital.