TEAM BLEND: CRITICAL PARTNERSHIPS IN STEM-FOCUSED INTERNATIONAL SERVICE LEARNING

BY ZACH POWERS AND MIMI WILCOX

Zach Powers, a KSTF Senior Fellow, is a co-founder and leader of Team Blend, an organization which engages high school students in STEM-focused international service learning projects. He taught physics, chemistry and environmental science for nine years in middle and high schools in and around the San Francisco Bay Area. In 2012, he began working as a school development coach with the New Tech Network, a network of schools using a project-based learning approach around the country.

Mimi Wilcox attended high school at Da Vinci Charter Academy, a New Tech Network school in Davis, California. There she was a member and student-leader of Team Blend for two years. She is currently studying Russian and economics at the University of Chicago, and intends to pursue a career in international development.

"El Centro Solar" - Home base for Team Blend operations, Sabana Grande, Nicaragua

BACKGROUND

Nicaragua is the second poorest country in the Western hemisphere, and the community of Sabana Grande is located in the second poorest municipality in Nicaragua. Yet Sabana Grande has become an shining example of what sustainable communities can look like in developing nations. With the help of Grupo Fenix, a Nicaraguan organization dedicated to promoting renewable energy sources in rural communities, they built the capacity of the residents to "research, develop, and apply appropriate, renewable energy technologies."

Davis, California, is the second most educated city in America and the home of Da Vinci Charter Academy, a small, public high school, which is part of the New Tech Network. Students at Da Vinci learn all of their subject matter content, along with key skills like written and oral communication, professionalism, and collaboration, through project-based learning. When science students from Da Vinci partnered with Grupo Fenix and enlisted the help of Peregrine International, a local educational and service-learning non-profit, Team Blend was born.

Now in its fifth year, Team Blend has completed four successful trips to Nicaragua. This is the story of how these three organizations found each other and worked collaboratively to develop and implement STEM-focused international service learning projects. Hopefully, this story can serve to inspire and illuminate the lessons learned for those who hope to engage in similar endeavors.

PROBLEM IDENTIFICATION

In the fall of 2010, the director of Grupo Fenix, Susan Kinne, arrived in Davis to give a talk at UC Davis. She had been invited by Gwynn Benner of the UC Davis Energy Efficiency Center and Deb Bruns, a local educator and board member of Peregrine International, to discuss potential avenues for collaboration with the community and university. Both Deb and Gwynn had traveled with their families to Sabana Grande to take part in service-learning projects. Susan described the recent construction of an off-grid restaurant in Sabana Grande powered entirely by solar energy. The structure of the restaurant was nearly complete, with solar ovens, efficient wood stoves, and bio-gas stoves to do most of the cooking, but the solar electrical system they had installed was not able to generate and store enough solar electricity to reliably run a blender necessary to make

"Bici-Bomba" - a student designed and built bike-powered water pump

"licuados," blended fruit drinks popular in Nicaragua.

Deb and Gwynn suggested that Susan present the problem to teacher Zach Powers, at Da Vinci. Zach was eager to find meaningful problems for his students to work on, and this new problem fit nicely with the energy efficiency project they were just completing. He was excited to engage his students with an authentic problem that incorporated both physics and engineering-design.

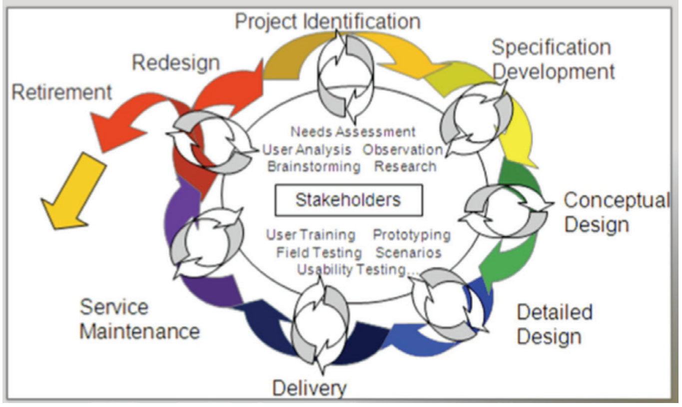
Since the students had already completed their energy project, he presented it as an option to fulfill honors-level project credit or allow regular-level students an opportunity to gain extra credit. To make sure the students understood this was an authentic, real-world situation and not a made-up scenario, Zach invited Susan to come to Da Vinci and present the challenge of the off-the-grid blender to the students, though Zach had no idea what the response would be. He hoped that at least a few students would be interested in spending some time working on the project, but when over 40 kids put their name on the list to be involved, he was struck with both excitement and trepidation. What did he just get himself into?

ENGINEERING DESIGN CYCLE

Zach now faced the problem that every PBL (project-based learning) teacher loves to have: how does the eager, excited, energy of 40 teens get converted into skills, knowledge, and actual products? Without a framework to guide and focus their efforts, they might spend a lot of time coming up with designs, but have no way to evaluate them, or perhaps worse, jump right into building something without really thinking things through.

Zach used the "Human-Centered Engineering Design Cycle," from "EPICS High," designed by Purdue University, to engage high school students in engineering through service to the community.

Human-Centered Engineering Design Cycle



EPICS High School Workshop, Perdue University

This shows the iterative, cyclical nature of the engineering design cycle which centers around the stakeholders (users) who will be interacting with the product. As the cycle moves from "project identification" through "specification development," the team starts by asking: "what are the needs we are trying to meet?" The question then becomes: "what are the constraints?" and "what does this product need to be able to do?" Students must answer these questions with as much detail as possible, and answers need to be based on what the stakeholders want and how they will use the product (as opposed to how the engineers *think* the users ought to use it). Doing this part of the process well is crucial to creating a product that actually gets used and maintained, as opposed to something that sits and gathers dust.

Once these questions are answered, engineers are able to move into brainstorming conceptual designs. After many designs have been proposed, they use the constraints and specifications to select the most promising design, develop a more detailed design (with associated drawings, measurements, and materials specifications), and finally build a physical prototype, which can be tested and improved before delivering the final product. Ideally, engineers will continue to interact with the users and be involved in evaluating the efficacy of the product as it is used "in the wild." Eventually, the product may either be re-designed or retired. In the next section, you will hear about this process.

YEAR ONE

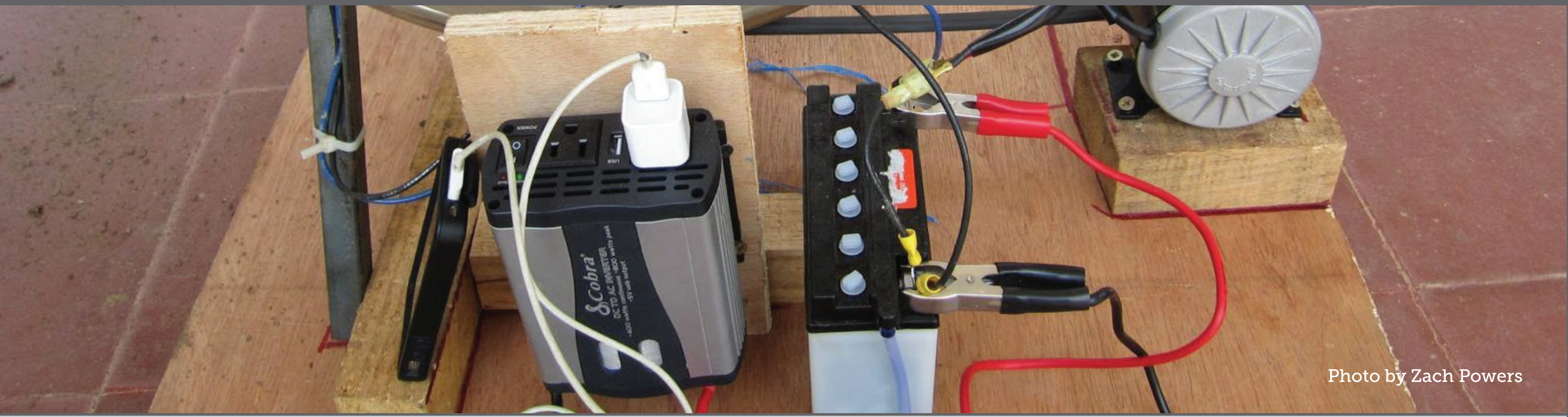
The team began meeting weekly in October 2010. In the early stages, students met with Zach at lunch each week to lay out the goals of the project and determine a timeline for the engineering process as well as fundraising and public outreach. The students quickly decided not to merely build a prototype and send it down to Nicaragua or make a how-to video, but to go to Nicaragua to work with members of Grupo Fenix to build blenders in Sabana Grande. The students' early embrace of the human-centered aspect of the design cycle partly influenced this decision. They decided that involving the members of Grupo Fenix in the design and build process would be the only way to ensure that the devices would not end up sitting broken or unused in a corner by allowing the members to take shared ownership of the project. This approach also would build engineering knowledge and skills in the community. The decision to turn a lunch-time science club into an international service learning trip was very much driven and owned by the students. It increased student engagement as well as the scope of what they needed to do.

With this in mind, the students got to work. The first step of the Human-Centered Engineering Design Cycle is to understand the nature of the problem and the stakeholders in order to develop a set of constraints and specifications that will drive the creation of design solutions. Students began brainstorming questions to help them understand the problem. With Zach's guidance, they honed these questions down to a list that would be useful for the design process: Who will be using the blending device? How will it be used? What kinds of foods will be processed? How often will it be used? Does it need to be mobile? If so, what kinds of roads will it travel on? What kind of maintenance might it receive? What kinds of parts, materials, and tools are available in Nicaragua? Will it need to survive outdoors? What building skills do the members of Grupo Fenix already have? After this process the students drafted an email with their list of questions, enlisted their Spanish teacher to help them translate it, and sent it off to Grupo Fenix. Once they had the answers, the group moved forward with a list of constraints and specifications.

Constraints (what limitations are there?)	Specifications (what does it need to do?)
• Built with materials available in/near S.G. (Sabana Grande): mountain bike parts, steel tubing, bolts, and wood • Built with hand-tools, hand-held drills, and a metal grinder only (solar inverter not big enough to run large tools) • No welding in S.G., can be done in a nearby town • All building should done by students and Grupo Fenix members • Relatively cheap to build	• Able to blend: cooked beans, fresh fruit drinks (not ice, no freezer) • Used in an off-grid restaurant, on flat ground, doesn't need to move • Used mainly by short women who wear skirts • Should not take large time or effort to use • Should be easy to maintain (will be done as needed by Grupo Fenix)

Students formed groups of two to four to research solutions that already existed, and they developed different conceptual designs (rough sketches). Each group presented their designs, which were subjected to a review process strictly focused on assessing how well the proposed design met the constraints and specifications (as opposed to whether students "liked" the design). Some designs seemed promising at first, but quickly fell by the wayside due to the complexity of design or build process, the limited availability of parts, or the price of the parts. For example, one group's design used a set of three inter-meshing gears to get the blender to spin faster. The reviewers decided that this would be costly to get gears like the ones in their design, almost impossible to build them with hand-tools, and almost impossible to replace in Nicaragua if they broke.

The team quickly decided that the students did not want to just build a prototype and send it down to Nicaragua; they wanted to go to Nicaragua.



"Bici-generadora" - a student designed and built bike-powered generator

It was at this point in the process that something miraculous happened. Students realized that they needed to understand a little more about physics before they could really move on with the design process, and started *asking to be taught physics... after school...with no test coming up!* Zach addressed the students' "need to knows" with an overview of work, energy, and simple machines. The students devoured this new information and put it to work immediately in evaluating designs. When they began asking about gear-ratios, it turned out one of the team members had experience with gearboxes from his work on the robotics team, and he gave a short mini-lesson to the group. To help students get access to real engineering expertise, Zach contacted Jason Moore, an engineering student from UC Davis with experience designing and building human-powered machines. Jason brought in graphs and data tables from kinesiology research to help the team understand how much power a human being could produce for different amounts of time. He also helped them evaluate the relative difficulty associated with fabricating or re-purposing a variety of parts (like bearings, gears, friction wheels, chains, etc.).

Once students felt they had a better grasp on the fundamentals, they were able to more efficiently and confidently decide on a final design, settling on a pedal-powered option that used a friction wheel to drive the blender shaft. High school students from Davis (a city dubbed "The Bicycle Capital of the World") understood and were excited by this technology. They had also learned in their email exchange that the people of Sabana Grande also used bikes on a regular basis and had bikes available to convert.

With help from Jason and Zach, the team created a final design for the blender (complete with dimensions and materials list) and went to work building a prototype. Though few students had any building experience, Zach had enough know-how to give guidance, maintain a safe working environment, and provide access to the basic tools (limited to hand tools, a drill, and a grinder as specified in the constraints) they would need to build the machine.

As the date of their trip drew closer, everyone understood that lunch meetings did not provide enough time. Because some students realized they couldn't make the time commitment, the group eventually stabilized at 25 students. Although initially disappointed, Zach found that working with the smaller, more dedicated group improved the quality of the time they spent together. This committed core decided to meet after school and on weekends each week to translate their design into a physical reality. They cut, drilled, and filed angle iron, tested the frictional properties of different materials, tore apart a few blenders, and tossed around ideas.

Many unanticipated decisions and roadblocks popped up, so the students periodically went back to the drawing board and tweaked the design, all the while conferring with Zach and each other on how to make adjustments when things didn't go as planned or when their original design proved unfeasible. After many meetings and revisions, a first prototype was finally complete. The students engaged in a rigorous testing period (i.e., making delicious smoothies) and some critical feedback sessions followed. Students decided to improve several issues, including the tire selected by the team that was too knobby to maintain constant contact, the mounting of the friction wheel's bearings, and the friction wheel itself which was wearing down too quickly. Students completed a second prototype a few weeks before the scheduled trip.

The team decided to leave these prototypes in Davis, bringing only ideas, experience, knowledge, and a sense of collaboration with them to Nicaragua in order to engage the members of Grupo Fenix in the engineering process.

THE FIRST TRIP

Along with the engineering process, the team planned and implemented a number of successful fundraising events to buy materials for construction and make their June departure possible. They had decided early on that no one should be excluded from the trip because of an inability to pay, and their dedication to this idea paid off through enthusiastic fundraising. Before they knew it, June had arrived. Eighteen students, along with Zach, Deb and Gwynn, boarded a plane to Nicaragua. Excited, a little nervous, and eager to implement all their ideas, they took off on a 10 day adventure.

The experience that followed was nothing short of life-changing. Students lived with local families, getting to know them and their customs. There was a language barrier, as almost no one in the community spoke English, but Spanish-speaking students were able to help with translation, and those who spoke little Spanish at the beginning of the trip quickly caught on. Students spent mornings at the local elementary school teaching science lessons about sound waves and magnetism and afternoons (after a lunch at the solar restaurant) working tirelessly with two sub-groups of Grupo Fenix to design and build two different bicycle blenders.

The first blender was built by the group of women who run the solar restaurant and had spearheaded learning engineering skills and investigating solar energy in their community. The second was built by a group of local high school students interested in renewable energy and engineering (many of whom were the children of the aforementioned women). By the end of the week, the original design had been improved by the collaborative work in Sabana Grande, and the community was left with two working bicycle blenders: one stationary bike and one portable bike with a fold-up stand. These would be used to make and sell licuados at community events (like Futbol and Baseball games). Nicaraguan students had conceived of this mobile blender just a few days earlier. It required a huge amount of creative design work to pull off a stand that was stable enough to hold the rear wheel of the bike off the ground while being pedaled, but also compact enough to fold up for transport.

Both design teams had many challenges to deal with. Some were fairly clear-cut and just required diligence, like not being able to find parts or losing electricity on a regular basis. But others were a little harder to solve. For instance, many of the Nicaraguan teens, who had little experience with designing or building anything mechanical, felt reticent to share ideas or use tools. It was difficult for members of Team Blend to not step in and fill the void. The team realized that, often, rather than asking in broken Spanish "do you want to drill this hole?" what they really needed to do was put the drill into the hand of their Nicaraguan teammate, smile, and point. Additionally, it quickly became apparent that to make sure both halves of the team were able to stay fully engaged, the Americans needed to speak Spanish whenever possible. When an idea was too complex to share directly, students would immediately get someone to help translate so the Nicaraguan members weren't cut out of the design process.

By the time they left, the members of Team Blend had stepped far out of their comfort zones, immersed themselves in a different culture, faced challenges they never expected, learned an extraordinary amount about the power of collaborative engineering between groups, and built two functional, human-powered blenders.

EVOLUTION OF TEAM BLEND

In the years which followed the overall process stayed roughly the same, even though the focus of the engineering project changed annually. Each year, starting in October or November, the team engaged in a seven-month engineering process while simultaneously raising funds to make sure all participants could attend. In June, the team traveled to Nicaragua for about two weeks.

Each year the mix of students is a little different. The trip has been opened up to all students at Da Vinci, rather than just physics students, so there is a wider range of ages and a mix of veterans and new members. Bekah Rottenberg, a life science teacher at Da Vinci, replaced Gwynn, who was unable to continue. She added an ecology component which generally involved research and application of sustainable agricultural practices within the community. The team continues to teach science lessons in the local elementary school each year. Engineering projects have included a bicycle powered electricity generator, a blender re-design, a bicycle powered water pump, and most recently a pair of cargo-transport bikes.

On their second journey the students had the opportunity to dive into the last section of the Human Centered Engineering Design Cycle: service, maintenance, and redesign. Though the original project had been focused on electrical power generators, they discovered that after a year of use and abuse both the blenders from the previous year needed some repair and re-thinking. The team decided to split into two groups; while one group worked on the generator project, another worked on the blenders. The previous year of usage had illuminated some short-comings in the design as well as some key places the blenders could be improved. In the stationary bike, they found that the drive-wheel they selected had begun to wobble and lose contact with the friction wheel, and the friction wheel was aligned in a way that unevenly wore down the rubber over time. For the mobile blender, the stand would not stay put when riding on bumpy terrain and needed a better mounting system to be a bit more stable when blending. Both groups got an important lesson in long-term prototype testing and iterative design. By the time the group left, both blenders were running well and much more functional.

During year three, the team built a pedal-driven water pump. Year four included the introduction of a municipal power line and the ability to weld in the workshop area. This opened up new avenues for the design of that year's project—cargo bikes. More importantly, this increased the level of ownership and engagement from the young Nicaraguan engineers, as welding was a skill they were actively learning but the American students didn't possess yet. After four years of engineering experience, some of the Nicaraguan youth are now becoming leaders within their community and posses skills which exceed those of the American students. This has changed the dynamic of the exchange in the last year or two, as there is more equal sharing between the groups.

STUDENT IMPACT

After returning from a trip to Nicaragua, students almost always speak of their perceptions of the world shifting in some way. For some students, this means becoming more appreciative of their families and the material things they have. This, by itself, is an amazing outcome. However, there are those who also talk about the Team Blend experience as life changing. Some may have joined mainly for the international service aspect, but along the way realized that science and engineering can play a role in improving the world, which helps them develop a love for these disciplines. Others, who might have joined because of the science, have their eyes opened to a country and a way of life they barely knew existed. For many, it is a first chance to be collaborative, creative, adventurous, and to exercise leadership.

After our inaugural year there was a very strong contingent of veteran students who stayed on the team. Some would support the growth of new members in Davis, while a few also participated in a second year of travel. This allowed much of the leadership (both in the logistical and the engineering process) to be assumed by these students. The students who chose to take this on grew immensely from the experience. In the words of a Team Blend member who became a student leader her second year on the team:

> There are not many programs offered in high school that emphasize collaboration in an international context the way that Team Blend does. I think it was quite a unique opportunity for me to be able to assume a leadership role in a peer group doing such important work. Being a leader pushed me to invest in the project in an even more serious way and strengthened a skill set that I frequently rely on in college. Because of my prior experience with Team Blend I was much more inclined to seek out similar leadership roles when I started as an undergrad. Thus far, I have been able to draw on my experiences with Team Blend in every one of those roles. I am currently participating in a year long study abroad program with other students from my university and I feel very strongly that my decision to apply was heavily influenced by my experiences with Team Blend.

CONCLUSION

The students in Team Blend learned about collaboration, communication, travel and other cultures, but their entire project was focused around

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STEM. By building the bicycle-powered blenders, generator, pump, and cargo bikes, students met STEM standards by learning about torque, gear ratios, simple machines, friction, geometry, electricity, efficiency, fluid dynamics, and the engineering design process.

Since the first year of implementation, many aspects have been tweaked, added, removed or improved, yet the core mission of the group has remained the same: to engage the members of Team Blend and their Nicaraguan partners in authentic, collaborative, meaningful engineering projects that have real-world value to people. Both groups have recognized the tremendous educational value provided by this opportunity and, true to the Human-Centered Engineering Design Cycle, are very conscious to gather and reflect on the experiences of all the stakeholders so that they might iteratively improve the process and outcomes for everyone.

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CITATION

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