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Skip the Grid: An Interdisciplinary Service-Learning Project Installing Solar Power in the Navajo Nation Case Study

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Skip the Grid is an interdisciplinary community service project-based senior project, with the pilot implementation completed in March of 2022, a second project completed in March 2023, and a 3rd project planned for March 2024. Facilitated through the non-profit Heart of America (HOA) and funded through the generous support of SOLV Energy and several industry and community sponsors, the project was completed by an interdisciplinary group of 26 undergraduate students and three faculty from California Polytechnic State University, San Luis Obispo (Cal Poly) over a two-year period. The project improved energy equity in the Navajo Nation by providing off-grid solar energy to 38 families of school age children living without electricity. This project comprised the design, planning, and installation of the off-grid solar photovoltaic (PV) energy systems consisting of PV panels, a battery with inverter and load center, and lights. The students on the project prepared for the implementation, collaborating across academic disciplines with industry partners and the community to provide complete working PV systems to families of school age children, primarily in the Red Mesa and Chinle Unified School Districts. This paper documents students' lessons learned to help other students and faculty initiate similar service projects in indigenous communities.

Key Words: Off-Grid Solar Power, Service Learning, Project Based Learning, Interdisciplinary Projects

Introduction

Skip the Grid is an interdisciplinary community service project-based senior project, with the pilot implementation completed in March of 2022, a second project completed in March 2023, and a 3rd project is planned for March 2024. Facilitated through the non-profit Heart of America (HOA), the project was completed by an interdisciplinary group of 26 undergraduate students and three faculty from California Polytechnic State University, San Luis Obispo (Cal Poly) over a two-year period. The project was funded through the generous support of SOLV Energy, Goal Zero, Live Action, Cupertino Electric, Prime Electric, Quiring General, Anvil Builders, and several community sponsors. The Skip the Grid project aimed to improve energy equity in the Navajo Nation providing off-grid solar energy to families of school age children living without electricity. This project comprised the design, planning, and installation of the off-grid solar photovoltaic (PV) energy systems consisting of PV panels, a battery with inverter and load center, and lights. Some of the homes also received DC refrigerators with more planned to be added. The students on the project worked for several months preparing for the implementation, collaborating across academic disciplines, with industry partners and the community to provide complete working systems to 38 families of school age children over two years, primarily in the Red Mesa and Chinle Unified School Districts of Arizona.

A team of undergraduate students from five out of six Cal Poly colleges completed a project that made a lasting impact on the Navajo community. The Navajo Nation has disproportionately high unemployment rates, high economic disadvantages, lack of basic utilities and a high percentage of households below the federal poverty line. Skip the Grid addresses some of these inequities and creates an opportunity for Cal Poly students to utilize skills developed in the classroom to create a more equitable future for the Navajo people. The Cal Poly students, through the help of HOA working with the Red Mesa Unified School District (RMUSD) Arizona and the financial and logistical support of SOLV Energy and our other sponsors the Skip the Grid team successfully provided reliable photovoltaic energy systems to 11 families the first year and 27 families the second year. The scope of the project for the students and the implementation team involved constructing a logistics plan, procuring materials and tools, creating user manuals, practicing system installation, conducting system testing, and composing a lesson plan for RMSUD K-12 students. Over the course of six months the interdisciplinary team of 8 students in the first year and 20 students in the second year organized, planned and practiced to deliver dependable electrical power systems to the most needy families of school age children of the Navajo Nation.

Literature Review

Construction management education primarily focuses on scheduling, estimating, and materials and methods, delivered via lectures (Chinowskly et al., 2006). However, these fundamental courses, while essential, are not comprehensive enough for the multifaceted nature of construction operations. A blend of managerial, technical, and interpersonal skills is also necessary (Ahmed et al., 2014). Traditional education, while effective in imparting specialized skills, often fails to address the integrative problem-solving needed in real-world contexts (Montoya et al., 2009).

Modern pedagogies like experiential and project-based learning stem from the constructivist theory, which posits that learners construct knowledge through experience and social interaction (Greenwood et al., 2017; Frank et al., 2003). These methods emphasize learning through action, with experiential learning focusing on self-reflective observation and discovery learning encouraging student-led exploration (Greenwood et al., 2017).

Problem-based learning (PBL) contrasts traditional lectures by promoting retention and application of knowledge through interactive, hands-on experiences, which also foster soft skills development (Barlow, 2017; Yildririm et al., 2014). Spiral learning (SL) complements PBL by reintroducing concepts progressively to deepen understanding (Veladat & Mohammadi, 2011). PBL, often paired with SL, has been shown to enhance student performance (Jamie et al., 2016).

Despite the benefits, PBL presents challenges like increased preparation time for educators and a need for foundational knowledge among students (Chinowsky et al., 2006; Yildririm et al., 2014). Additionally, group dynamics in PBL can create obstacles (Gunderson & Moore, 2008).

Preferences in learning styles vary, with some students favoring less demanding passive learning (Kumar et al., 2004; Frank et al., 2003). Nonetheless, interactive, hands-on methods are often seen as more effective (Kolgraff et al., 2019, Kolgraff et al., 2021, Kline et al. 2022, Cleary et al., 2022). PBL and SL environments not only enhance learning but also prepare students to collaborate beyond their comfort zones and tackle real-world projects (Gunderson & Moore, 2008; Maghiair et al., 2015). Students clearly benefit from involvement in the learning environment provided by a real-world project with a specific purpose and intended outcome (Cleary & Starzyk, 2020) These projects can be completed in partnership between students, faculty, and professionals to achieve completion of an outcome (Malekmohammedi et al., 2021). This case study will document student self-reported learning outcomes in an interdisciplinary, community service based, learn-by-doing real world project-based senior project with multiple stakeholders.

Background

The project took place in the Navajo Nation, a Native American reservation spanning more than seventeen million acres of the Four Corners region of the US, including parts of northeastern Arizona, southeastern Utah, and northwestern New Mexico. The people that reside there are the Diné, meaning "The People" in Navajo. The RMSUD, a K-12 school within the reservation, connected with the education-based non-profit group HOA in 2020 during the COVID-19 pandemic to help support distance learning for families without the resources to continue learning or meeting basic needs when the schools shut down due to the pandemic. Many didn't have computers, Chromebooks, internet access, or power. These families and students were disproportionately disrupted during the shutdown and needed additional resources to stay on their academic track and keep up with their peers. SOLV Energy, one of the largest PV installers in the US was in the process of building the first native owned PV power plant in the area and began working with both HOA and RMUSD to see how they could help the community. In 2021 representatives from SOLV Energy met with faculty from Cal Poly and discussed what would be the first Skip the Grid installation in March of 2022.

According to the Navajo Tribal Utility Authority an estimated 13,500 homes, sheltering approximately 67,500 American citizens in the Navajo Nation are living without electricity. This reality is due to the difficulty of getting a homesite construction permit and the high poverty rate in the area, resulting in many people living on their own land in makeshift homes. Many of these homes are not eligible to have a grid power connection because they aren't federally approved homes. Many don't have a grid connection due to the remote nature of the homes, and many because it's cost prohibitive for the family economic situation. This includes families of school-age children, many of these students ride the bus for 2 or more hours each day and spend much of the school year leaving for school in the morning when it is still dark and returning in the evening when it is dark again. With no electrical power in the home there are no reliable lights to do homework, read, draw, etc. at night. Some of the homes use kerosine lanterns and heaters, some wood stoves, others have gas or diesel generators, even some use their vehicle battery to charge their phone or provide power to the house. Flashlights and other battery powered devices are also used when the families can afford the batteries. All these bad options contribute to very difficult learning environments for students to do homework after school and that is something the Skip the Grid project aims to address for those most in need.

Project Preparation

Skip the Grid is an interdisciplinary community service project-based senior project beginning in 2022 that improved energy equity in the Navajo Nation by providing off-grid solar energy to families of school age children living without electricity. Facilitated through the non-profit HOA and funded through the generous support of SOLV Energy and several industry and community sponsors, the project was completed over two years by an interdisciplinary group of undergraduate students and faculty from Cal Poly. This project comprised planning and installation of off-grid solar PV systems.

Project Team

In year one of the project, an interdisciplinary team of 8 Cal Poly students made up of 4 Construction Management (CM), 2 Mechanical Engineering (ME), 1 Electrical Engineering, and 1 Political Science, and 3 faculty undertook the first solar PV system installation project of this partnership. In the second year the team grew to 20 Cal Poly students selected from a large pool of interested students generated by buzz from the first year. The team included students from 8 majors and 5 of the 6 colleges including 6 CM, 8 ME, 1 Architecture, 1 Environmental Engineering, 1 Economics, 1 Graphic Communications, 1 Math, and 1 Spanish. The team was guided and advised by CM Department Head, Jeong Woo, CM Assistant Professor, Joseph Cleary, and ME Associate Professor, Jacques Belanger. The second-year team included 2 members from the previous year that conveyed lessons learned, assisted in the training, and lead the teams.

The initial year of the installation the students were divided into two installation groups of four students, a faculty member, an HOA representative, a SOLV representative, and a community liaison from the RMUSD. In the preparation for the second year, students organized themselves by their interest into five different groups: construction, system testing, cultural, education, and fundraising. Responsibilities were divided so that team members could focus on specific tasks or areas of expertise. Individuals developed a deeper understanding and skill set in their expert groups to help increase efficiency and productivity to deliver results. Students also created a logistics plan early in the preparation that led the teams to reorganize into functional groups to prioritize the installation priorities within the teams. Team members had specific responsibilities during installation; PV orientation and installation assessment; roof assessment and ladder safety; staging and preassembly of materials and tools; and interior assessment coordinating the primary cable penetration, and lighting.

Logistics

In the first year of the project the team traveled by plane from San Luis Obispo, CA to Durango CO and drove four-wheel drive SUVs to Bluff, UT where the team stayed for the four days of their project during Cal Poly's spring break. That location is north of the RMUSD campus in AZ and acted as our base of operations. The second year, again during Cal Poly's spring break, the team flew from San Luis Obispo, CA to Phoenix, AZ then drove four-wheel drive trucks and SUVs to the hotel at Bluff, UT and again staged our operation out of the RMUSD campus. In both years of the project the home sites receiving the installations were pre-selected by HOA in conjunction with the family liaison at the local school districts. In year one the installations were all in RMUSD.

In year two the team continued installations in RMUSD as well as neighboring districts including Chinle, AZ. In preparation for these installations, HOA sent the Cal Poly team coordinates of the home sites. In that area of the country there aren't formal addresses, and the coordinates were the best way to identify the location of the homes. The advanced team in most cases got pictures of the exterior of the homes prior to mobilizing to the site for planning purposes. As it turned out there were many different home types, roof types and conditions. The team had to plan for installation procedures that would work for all types of home configuration as there likely wouldn't be an opportunity to return to a hardware store for more supplies and revisit the site later. This was one of the greatest challenges in preparing the students for this project. Figure 1 shows a Google Earth image of coordinates from one of the homes sites, the picture provided by the advanced team and the actual installation.

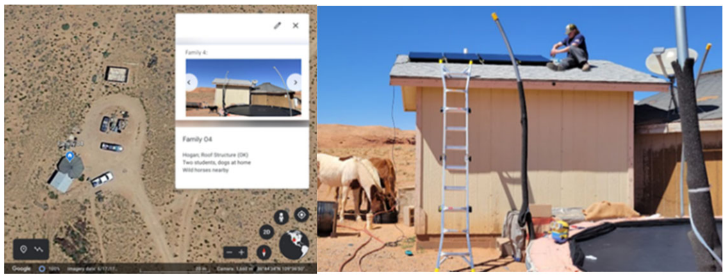

Figure 1. Site Planning using coordinate data from HOA and Google Earth (left), and field installation at the same site (right)

System and Products

The solar/battery system was similar both years and consisted of four 100W Goal Zero Solar PV Panels, and two Goal Zero interior lights. Year one included a Goal Zero Yeti 1500X Power Station, and a Dometic DC CFX Medium-Sized Refrigerator (Figure 2). The Second year included a Goal Zero Yeti 1000X Power Station, and no refrigerator, with plans to deliver one in the future.

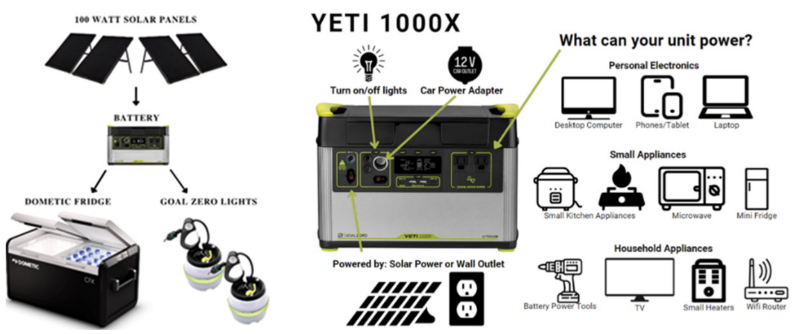

Figure 2. Skip the Grid system (left) Example of Systems Owner Manual for 1000X (right)

Both years the system components were sent in advance to RMUSD where they could be staged for installation. After a lesson learned the first year, the products were packaged in bulk second year, and didn't require unboxing, greatly reducing the waste and the effort from year one.

Estimating and Procurement of Tools and Materials

Estimating the necessary tools and materials needed for each team was an extensive process performed by a student team. The closest hardware store to our base of operation and installation locations is several hours away, so the team had to account for all eventualities for tools, fasteners, sealants, PPE, first aid, etc. The first year the team bought some of the materials and prepped on campus prior to the trip and bought materials that were heavy, bulky, etc. in Durango before heading to our base of operations. The second year the teams traveled with heavy duty toolboxes, a great improvement on the first installation. A key point was placing the power tool batteries in a team member carry-on as they couldn't travel on the plane with the checked items. Bulky and heavy items, aerosols and other items that didn't need to travel with the team on the airplane but would be available at any hardware store were picked up in Phoenix upon arrival.

Education and Training (Practice Installations)

For both years of the program, an extensive education and training program was developed. In the ten weeks prior to the trip, the students in the different groups would work to accomplish their specific tasks and the entire team would meet weekly to share their progress. To prepare for the solar system installations in the Navajo Nation there are several trainings needed: cultural training, understanding the system and optimal orientation, roof inspection and planning of the installation, ladder safety, roof work safety, material handling safety, cable penetration for the main power cable, connecting the system, installing the lights, testing the system, and providing instruction to the beneficiary family. Cultural sensitivity awareness training was also included in these meetings. The group involved in the education program developed a series of educational tools in cooperation with HOA and SOLV Energy. The group spent an entire day with the students of the RMUSD to increase their awareness of STEM opportunities. The ten-week preparation was also used to test the systems and prepare the students for the installations in the Navajo Nation. A few weeks prior to the trip, four full days were dedicated for complete installation rehearsals on the Cal Poly campus. Two training sessions were held for the entire team lasting four hours each on installation and safety training for ladders, roof work, leading edge work, working under the edge of the roof etc. In addition, each installation team had two practice installation days lasting two to four hours each where they practiced going through a full installation as a team, in their team roles and with the tools they would use on site. The students used tiny houses built by the residential construction course as the models for their installation.

Installation

In both years of the project, on the day following arrival, the teams prepared for installations. This preparation involved inspecting and staging all the solar equipment previously delivered to RMUSD. It also involved preparation and loading of the vehicles with all the necessary materials and tools needed for the installations. After all preparation work was completed, installations were completed both years. Lessons learned from the eleven systems installed year one advised the process for year two. In the second year, two teams went to complete one installation each on the staging day. These first installations were designated to give the teams a chance to test their preparation and allow them to assess their installation procedures and plan adjustments in a debriefing that evening. This first installation day was followed by two full days with each team installing three to four systems per day.

Summary and Lessons Learned

The Skip the Grid project has successfully completed 38 off-grid PV electrical system installations over two installation windows, a year apart, involving 26 interdisciplinary students, and 3 faculty members from Cal Poly along with HOA, SOLV, and community partners in the Red Mesa and Chinle School districts. The project was marked by several key lessons and successes. The team faced challenges beyond their educational preparation in logistics, communication, and installation techniques that had to be overcome. The students each wrote a senior project report and project evaluation documenting the project and their lessons learned. The lessons learned were compiled by the authors and evaluated for similarities and themes. The student statements have been categorized and paraphrased. The key takeaways from the first-year installations from the student feedback fall into six main areas including; adaptability and problem solving, efficient communication and planning, teamwork and leadership, practical learning and future guidance, community impact, and sustainability and maintenance. In each of those areas the summary of the student reflections was captured and paraphrased here. Adaptability and Problem-Solving: The team's ability to quickly identify and address bottlenecks was crucial. For instance, they adjusted their tools and installation methods after realizing the impracticality of some pre-planned methods, demonstrating flexibility and resourcefulness. Efficient Communication and Planning: Improved communication and time management, especially from the second day of installation, significantly enhanced the team's efficiency. This was aided by streamlined planning such as predrilling panels and using Google Earth for optimal panel placement. Teamwork and Leadership: The project benefited greatly from team bonding activities, mentorship in construction practices, and effective leadership. These elements fostered confidence, clarity in roles, and efficient collaboration among team members. Practical Learning and Future Guidance: The experience provided valuable insights for future projects, including the importance of having alternative installation methods and the need for neatness and organization of tools to avoid delays. Community Impact: The project successfully equipped selected Navajo Nation families with the means to charge devices and use solar generated electricity to power appliances, thereby reducing educational barriers and improving their quality of life. This initiative was particularly impactful for beneficiary children's education, as it facilitated homework completion and access to technology. Sustainability and Maintenance: Teaching families about the equipment, usage, and maintenance ensures the longevity and sustainability of these installations and the family benefit of it. Overall, despite initial challenges, the project was successful in terms of team collaboration, problem-solving, student learning and providing tangible benefits to the selected families, setting a solid foundation for future similar initiatives.

After the first year there were five main areas of improvement identified directly from the students' lessons learned document. 1. The team should prioritize early preparation including a focus on project management including effective delegation of tasks and responsibilities. 2. Enhanced advanced field data collection, including details like tree locations, roof tilt, and orientation, was recommended to support future efforts. 3. Utilizing social media to raise awareness of the conditions and efforts in the Navajo Nation. 4. Provide a walk-through installation to help students better understand communication techniques, timing, and installation methods. 5. Greater emphasis on safety guidelines, with clear goals and responsibilities for managing risks in the field. These lessons informed the team and preparation for the second year of installations.

The key lessons from the second year from the student reports and feedback include interdisciplinary teamwork, effective communication and planning, preparation and adaptability, cultural sensitivity and community impact, learning and growth, and future impact. In each of those areas the summary of the student reflections was captured. Interdisciplinary Teamwork: The project's success was significantly boosted by the interdisciplinary nature of the team, involving students from multiple Cal Poly colleges. This diversity of skills and perspectives contributed to a more effective and adaptable problem-solving approach. Effective Communication and Planning: Open and clear communication among stakeholders, regular team debriefings, and early risk assessment were crucial for smooth operations. These strategies enabled the team to anticipate and mitigate challenges efficiently. Preparation and Adaptability: Extensive preparation, including practice installation sessions and composing installation teams methodically, played a vital role. The team's adaptability was evident in their ability to streamline the installation process, such as determining optimal panel placements and organizing tools more effectively. Cultural Sensitivity and Community Impact: The project not only focused on technical aspects but also on understanding and respecting the cultural context of the Navajo Nation. This approach not only facilitated smoother project execution but also ensured that the installed systems were well-received and beneficial to the community, particularly in improving educational opportunities for children. Learning and Growth: The project provided valuable learning experiences for the students, ranging from logistical organization to safety planning and cultural awareness. These lessons extended beyond academic knowledge, contributing to their personal and professional development. Future Impact: The success of Skip the Grid 2023 sets a precedent for future projects. Plans to expand and improve the initiative are in place, aiming to reach more families and further reduce educational and technological disparities in the Navajo Nation. In summary, Skip the Grid exemplifies the impactful combination of interdisciplinary collaboration, thorough preparation, community engagement, and adaptability for a rich educational experience. It stands as a model for future projects aimed at bridging energy inequity and empowering communities through sustainable solutions. This paper highlights the successful aspects of Skip the Grid, providing insights into planning, preparation, logistics, resource management, training, and installation. It would serve as a benchmark for educators who want to conduct similar projects with successful strategies.

Recommendations

From the summary of the student reflections the Skip the Grid 2023 project surpassed its objectives despite various challenges, with the team's quick adaptation to bottlenecks being a key strength noted by the students. From the first-year summary of student reports, recommended improvements were identified in areas of organization and logistics, engineering and testing, outreach, installation methods, and safety guidelines emphasizing early preparation, enhanced data collection, effective use of social media, and clear safety measures. These recommendations can be seen in the adaptations and improvements in year two preparation. The second year's summary of the student reports recommends focusing on earlier procurement of materials, cultural lessons from RMUSD for better cultural understanding, collaboration with campus clubs, and the development of a construction program to clearly outline project expectations. A comprehensive list of tools and materials was created to ensure future teams are well-equipped, laying a solid foundation for the continuation and enhancement of the project's impact. While funding could be a restrictive challenge, this program could expand to multiple times per year or expand to include students from other universities.

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