Promoting Sustainable Development Goals Through Project-Based Learning: A Case Study of the Concept Center

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Abstract

The field of engineering is well-suited to solve many of the United Nations 17 Sustainable Development Goals (SDGs). It is the responsibility of institutions of higher learning to prepare engineering students to not only understand their role in achieving these goals but to be equipped with the skills, knowledge, and expertise to make incremental changes and advancements in their field that support sustainable development. One such way to do so is through experience in project-based learning (PBL). The Concept Center at Weber State University is modeled after PBL and functions to pair students with sponsored projects. This paper discusses the application of PBL in the Concept Center to achieve a double mission of being an active community member by connecting academia with industry and community members and providing opportunities for students to gain needed skills in problem solving and project engineering and mentorship. A summary of past projects completed at the Concept Center by student interns is presented that demonstrate the ability of the PBL Center to advance goals related to good health and wellbeing (SDG3), quality education (SDG4), gender equality (SDG5), affordable and clean energy (SDG7), and industry, innovation, and infrastructure (SDG9).

Keywords: engineering education, project-based learned, United Nations Sustainable Development Goals, quality education, gender equality, affordable and clean energy, industry, innovation, and infrastructure

Introduction

The purpose of this paper is to provide the evidence, framework, and benefits of utilizing a Project-Based Learning (PBL) center to advance the United Nations SDGs that are relevant and custom to the local community.

PBL is a pedagogical approach where the learning centers around problems (Krajcik and Blumenfeld, 2005). The Concept Center at Weber State University is designed as a living laboratory for students to gain hands-on experience through PBL. The Concept Center strengthens the university's time-tested mission of teaching by expanding that mission to include the conversion of knowledge into solutions to real world problems. The Center employs undergraduate student interns from the College of Engineering, Applied Science and Technology (EAST) in a part-time capacity. The Concept Center is organized into two components which represent the mission of the Center:

Education

The Concept Center is a proving ground for student interns to work on sponsored projects under the direction of faculty mentors. This hands-on experience allows student interns to be better prepared to meet the demands for the modern workforce. By gaining more experience in communication, and broadening their understanding to encompass the economic, social, environmental, and international context of the engineering field, the student intern education is strengthened.

Research and Development

The Concept Center is a place where new knowledge, technology and capability are constantly being expanded. It can meet a variety of different needs that industry will encounter during their research and development activities ranging from development research to product development.

The Concept Center at Weber State University was not created to address the need to meet the 17 goals, however each project that is detailed in this paper explicitly does advance one of the 17 goals in parallel with supporting the goal of quality education. By design, the Concept Center is intended to promote quality education but intentionally selects projects and engages in activities that promote good health and wellbeing, gender equality, affordable and clean energy, and industry, innovation, and infrastructure. The application of meeting these goals is customized and relevant to the local community or individual sponsoring the project. By focusing on the goal of quality education, students gain experiences that would be impossible to achieve in a classroom setting working on sponsored projects that function to promote one or more of the SDGs.

Methodology

This paper describes the organization, framework, and operation of the Concept Center at Weber State University and provides an example of diverse projects that have been completed and their link to at least one of the SDGs. Foss and Liu have described the benefits of the Concept Center as a means of developing creativity (Foss and Liu, 2021) and allowing students to gain skills in technology (Foss and Liu, 2020) as well as identifying key benefits to the institution as well as key lessons learned in student intern management and methods in selecting and identifying appropriate projects (Foss and Liu, 2021). Liu and colleagues have also had success integrating PBL methodologies in the classroom setting to improve the learning outcomes of students (Liu et. al., 2011; 2015; 2017 a & b & c; 2018; 2019 a & b).

The projects that are selected by the Concept Center are invariably tied to at least one of the SDGs. Many past projects target the goal of good health and wellbeing that are addressed here. This paper will also explicitly demonstrate the unique ways the Concept Center advances the goal of quality education through projects, intern mentorship, and outreach to the local community. This paper will also address the ways that the Concept Center takes an active role in promoting the goal of gender equality by engaging in activities that are designed to promote and support

women in engineering. Additionally, this paper will highlight several completed projects that promote the goals of affordable and clean energy and industry, innovation, and infrastructure.

Findings

This paper provides evidence of success by detailing projects completed at the Concept Center that support many of the SDGs including SDG3-5, 7, and 9.

SDG3: Good Health and Wellbeing

The Concept Center has a history of projects that have been completed that promote SDG3.

One example project is the design and prototype of tactile braille display hardware as shown in Figure 1. This prototype was completed with an aim of developing a tablet designed for users with visual impairment so that users can utilize technology that has been inaccessible to the blind and visually impaired community. Work on this sponsored project has been completed and delivered to the customer for further improvements in design and usability.

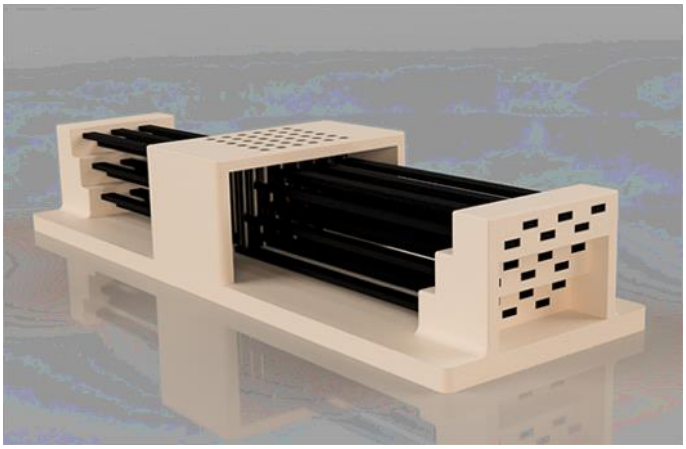

Figure 1. Tactile Display Hardware

In another project, the Concept Center designed and fabricated an athletic tape dispenser product for a student that only had one arm that was completing his studies in the athletic training degree. The product needed to accommodate multiple rolls of athletic tape as well as have the ability to cut the tape at custom lengths with one-handed operation. The Concept Center began by looking for solutions that could meet the customer requirements and created a simple and low-cost prototype that was belt-mounted and used a cutting wheel and slider as well as an easy quick-release mechanism for changing and replacing tape rolls as shown in Figure 2. This is an example of a project that meets the custom needs of an individual in the community and allows the individual to continue to advance in professions that would otherwise be limited.

Figure 3 shows a completed prosthetic guitar pic that was designed and built for a guitar musician that has only one arm. This device was designed with a removable insert so that musician could

utilize existing guitar picks. These projects are examples of projects that the Concept Center engages in that allow for the use of technology to solve real problems related to the health and wellbeing of members of the community.

Figure 2. Athletic Tape Dispenser for one-armed operation

Figure 3. Prosthetic Guitar Pick

Figure 4 shows the completed prototype of another project that had very unique requirements. A group of philanthropic eye doctors wished to come up with a device to administer an eye exam in a field setting. These doctors intended to travel to low income areas and Native American tribal lands to administer eyes tests for residents in those communities. They needed a product that could easily disassemble and fit in carry-on luggage, be light-weight, and low-cost and allow for

customizable settings to complete the exam. The Concept Center, working in conjunction with a team from the University of Utah designed and built a prototype that met the needs of the customers as shown in Figure 4.

Figure 4. Eye Exam Stand

The Concept Center has also worked on a number of projects that are subject to non-disclosure agreements (NDAs) and cannot be discussed in detail such as an innovative intubation tool. This tool is designed to aide a healthcare provider in keeping the airway open so air can get to the lungs in high risk and specialized populations of patients. Many projects completed by the Concept Center are selected due to their ability to promote SDG3.

SDG4: Quality Education

Improving Educational Outcomes

Many successful projects completed through the Concept Center have resulted in significant advancements in teaching within Weber State University and improvements in educational outcomes. In these projects, the clients are faculty or staff members of the University who were looking for solutions for their courses to improve the quality of the education of the course. A few examples of the developed teaching aids are Deming's Red Bead experiment for the course Quality Concepts and Statistics in the Manufacturing Systems Engineering (MSE) Department, I-beam molds for laboratory use in the course Reinforced Plastics/Advanced Composites in the MSE department, 3D printed self-assembling bacteria for Introductory Microbiology in the

Microbiology Department shown in Fig. 5, Leidenfrost effect blocks for several courses in the Physics Department, and a laser pointer assessment tool for the course Human Anatomy in the Zoology Department shown in Fig. 6. Lastly, three senior project teams in the Mechanical Engineering Department engaged in an autonomous robot competition where each team had to design a robot that would follow a course and launch a projectile at a target from different pre-determined locations. The Concept Center designed and fabricated a table-height 9-foot by 10-foot flat seamless surface equipped with side barriers and target locations that could be easily stored compactly when not in-use for use in the robotics course competition.

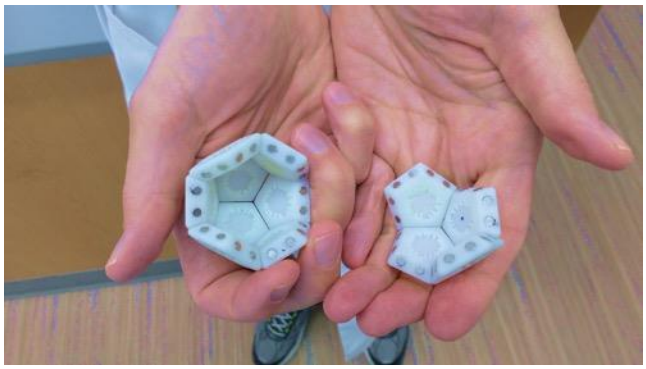

Figure 5. Self-assembling Bacteria

Figure 6. Laser Pointer Assessment Tool

Another example of projects completed that are aimed at improving student learning outcomes is demonstrated by the cadaver storage system. The Zoology Department at Weber State University received two cadavers by donation for use as teaching aids. A faculty member in that department wanted to use these cadavers in undergraduate human anatomy courses but did not have a way to store them. Moreover, the department did not have a budget or funding access to purchase a cadaver storage system. The Zoology faculty member approached the Concept Center for help with a temporary and a long-term storage solution for the cadavers. Based on the

customer's requirements, the team began by dividing this project into two phases. The goal of the first phase was to provide a short-term solution for the summer term and the goal of the second phase was to develop a long-term solution for permanently storing the cadavers in the Zoology Department. The Concept Center delivered to the Zoology department a low-cost and short-term solution and a longer-term solution that involved redesigning an existing gurney and equipping it with a pump and recirculating spray system as shown in Fig. 7. There were several important learning outcomes and unique design features included in this project that Foss and Liu have detailed (Foss and Liu, 2021).

Figure 7. Cadaver Storage Solution

Another project that was completed was the development of a mold for a mannequin shoulder insert. A faculty member from the Department of Zoology wanted a mold that could be used to make gel shoulder inserts for a mannequin for a continuing medical education (CME) accredited class for the Ogden Surgical-Medical Society's 2018 annual meeting. The gel shoulder inserts would be used in a technical training course for attendees led by a faculty member from the University. The mold was designed to allow attendees who are doctors, nurse practitioners, and physician assistants to practice injecting corticosteroids into various joints of the shoulder that are prone to damage. In this technical training course, CME students could visually see the location where the dye was delivered to simulate an injection of medicine on a real shoulder. Using the

mannequin provided by the Zoology faculty, the team made a reusable silicon mold. Fig. 8 shows the mold made in progress for the mannequin shoulder.

Figure 8. Mannequin shoulder mold teaching aid in progress

Mentoring Student Interns

Student interns can benefit the most from the PBL center through the mentoring relationship. The importance of mentoring experiences cannot be overstated and yet it rarely receives the focus or attention in academic culture (Committee on Effective Mentoring in STEMM, 2019). At the Concept Center, each student will have varying and individual needs. One student may need instructions on research methodologies or the use of technology. Fig. 9 shows students gaining skills in the operation of a CNC Plasma Cutting table. Another student may need guidance in interpersonal and communication skills. It is the responsibility of the mentor to assess the needs of each student intern and guide them accordingly. The role that the mentor plays should be tailored for each student intern. Each mentor should meet with student interns individually, document their goals of development, and discuss ways of assessing their progress.

Figure 9. Students gaining skills in technology through mentoring

Active Community Member

The Concept Center plays an active role in advancing quality education by volunteering to host sessions at local elementary schools for science fairs and STEM days. Faculty and interns at the Concept Center design PBL related challenges and provide materials to elementary-age children for STEM day

Concept Center faculty also engage in judging science fairs at local elementary schools and mentoring of winning students as they progress to the next level of the science fair. To do so, one faculty member met individually with 17 6th grade students and provided them tailored feedback and coaching to improve their poster, scientific method and presentation delivery. Many of these students received ribbons and advanced to the regional science fair that is scheduled for late spring, 2022. In this way, The Concept Center can promote SDG4 to not only the institution but also the local community.

SDG5: Gender Equality

The Concept Center plays an active role in promoting SDG5 by supporting women in engineering through outreach activities. The role that women have played in the field of engineering is historically complex but is also changing. In 2007 in the United States, 2.6% of freshmen women had intentions to major in Engineering compared to 13.7% for men. By 2014, the percentage of freshmen women intentions increased to 5.8% while for freshmen men the intentions increased to 19.1% (Science and Engineering Indicators, 2016). These increases in both genders show a marked improvement that could be attributed to many factors, including focus on Science, technology, engineering and math (STEM) in primary and secondary education. However, despite these advances, there remain interesting trends in retention of underrepresented minorities (URM) students in STEM fields. Proportionally, 32% of females left STEM fields by switching to a non-STEM major compared to 26% for males (Chen, 2013). There also exist significant gender imbalances within these fields in both the educational setting as well as industry. For example, the percentage of women working as engineers is 8.7% for mechanical and 11.8% for electrical and electronics (Labor Force Statistics from the Current Population Survey, 2022). The stark gender imbalances within engineering disciplines creates a catch-22 situation. More women would be represented in the educational setting and in industry if a critical mass of women could be achieved, eliminating or reducing challenges related to stereotypes and

stereotype threat and belonging. The Concept Center prioritizes promoting SDG5 within engineering by engaging in a number of outreach events sponsored by the University that are designed around PBL and also intended to create an environment that where belonging is fostered.

Parent Daughter Engineering Night

Many agree that a parent is a child's first teacher. The inspiration for the Parent Daughter Engineering Night Event hosted by Weber State University is based upon this premise using principles of problem-based learning (PBL). This event has been hosted for a period of eleven years with the past 5 years including Foss, the director of the Concept Center, as an event planner and facilitator.

In the setting created by the event, parents see their daughter in a positive atmosphere that not only supports but demonstrates the place of women in engineering. Additionally, the daughter, with a target age group of grades 7 through 12, can find herself in a group of her peers engaging in hands-on engineering activities and hearing the stories of women in engineering as students or in their careers. The result is both parties can share in an experience that uplifts and supports women in engineering and visualize a potential future for the daughter in engineering. Figs. 10 and 11 demonstrate the inclusive nature of the event, the application of PBL in the event design and the culture that is fostered to promote gender equality for women in engineering.

Figure 10. Parent-Daughter Team solving PBL Challenge

Figure 11. Daughters presenting their PBL Hydraulic hand challenge

Girls Welding Camp

Another outreach event that has been supported by the Concept Center is a summer camp that is hosted by Weber State University is the Art and Science of Metalwork through the medium of welding. This hands-on overnight camp targets 7-12th grade girls and exposes students to metal inert gas (MIG) welding, computer aided design (CAD), metal cutting processes such as plasma and waterjet cutting. The Concept Center supports this camp by serving as an instructor, planning the PBL design and build challenges completed by the students, and preparing materials needed for the camp. Figs. 12 and 13 show attendees of the camp participating and learning the welding process in an environment that is inclusive and designed to promote gender equality in a field where there is minimal representation from women.

Figure 12. Attendees of Welding Camp

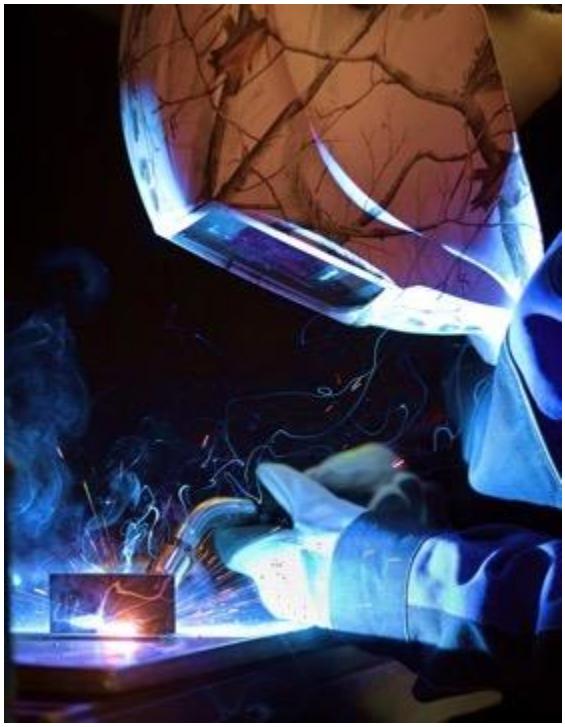

Figure 13. Student Welding Art Project

Affordable and Clean Energy

The Concept Center prioritizes projects that target SDG7. One example project that was completed was the design and fabrication of two solar powered pavilions. The goal of the Solar Pavilion project was to design and fabricate two solar powered pavilions equipped with lighting and charging sources to power electronic devices. The primary goal of this project was to provide a safe and attractive place for students to convene, study, and work together outside. There were no such areas for students on the campus at that time and the cost of installation to run a new power line to a remote part of the campus was prohibitive and against the campus goals of sustainability.

At the completion of this project, two solar pavilions were installed on campus. Student interns gained hands-on experience in design and fabrication of the corrosion-resistant metal structures and accompanying solar power lighting and charging stations. In carrying out this project, they also developed skills in troubleshooting, teamwork, and problem solving. One completed solar pavilion with a student user is shown in Fig. 14. The pavilions have been in operation since June of 2019. The Concept Center has been monitoring their performance since then and has verified from student feedback that the solar powered pavilions function well in providing lighting and outdoor charging access for students.

Figure 14. Completed solar pavilion

This project led to another partnership with a community partner to design and build a solar powered bus stop shown in Fig. 15. This bus stop was designed to utilize clean energy (solar) to

power a light and an electronic display screen that could display the bus schedule as shown in Fig 16.

Figure 15. Solar Powered Bus Stop

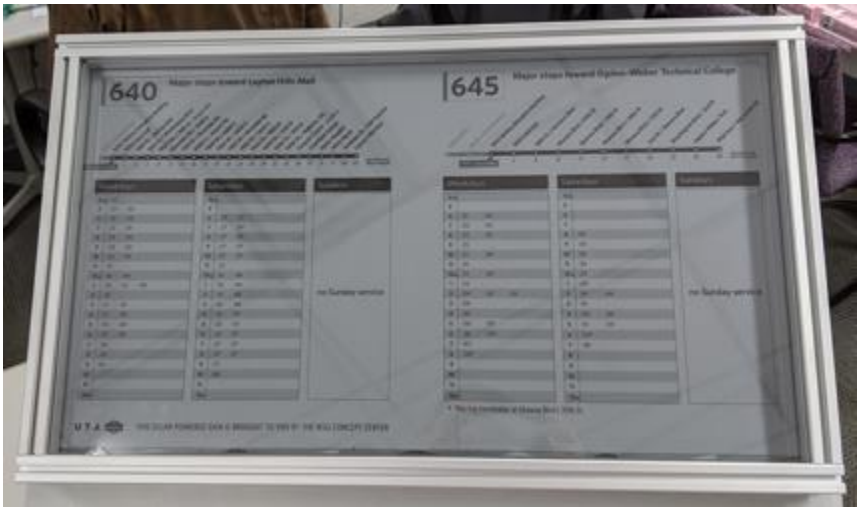

Figure 16. Solar Powered Programmable Display Screen

Industry, Innovation, and Infrastructure

The majority of the industrial partners that have sponsored projects completed at the Concept Center are subject to NDAs so cannot be discussed here. There are, however, some projects that have been completed to support research projects that can be detailed.

Fig. 17 shows the CAD rendering of a test fixture device intended for a start-up corporation working on an innovative vehicle system. This test fixture was designed and fabricated by the Concept Center and allowed the company to better understand weak areas of their design by allowing the component to be tested to failure in an INSTRON machine. Loading conditions that will simulate its use were applied to the device and the customer was able to determine that the component needed to be redesigned to handle the loading that it will experience in use.

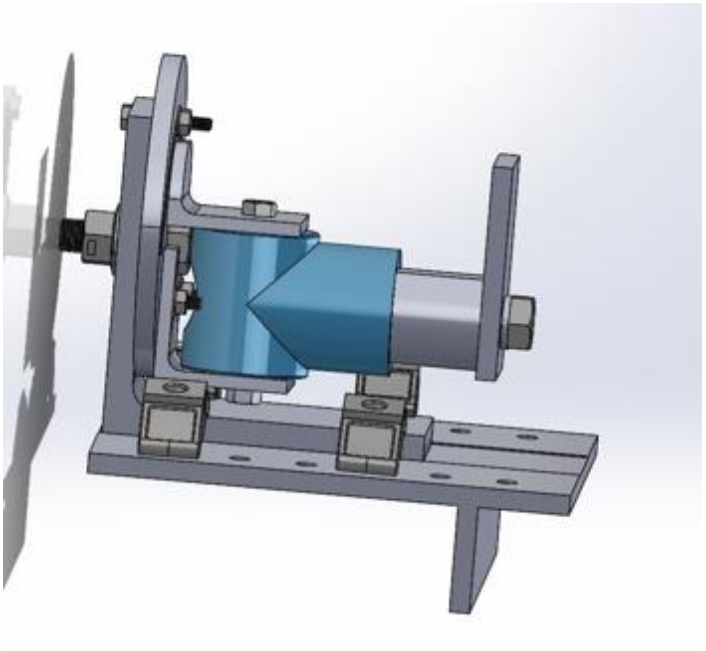

Figure 17. Test Fixture

Fig. 18 shows the completed devices designed and built by the Concept Center to test the water quality at a high elevation lake in a sensitive environment in Utah. Fish Lake is located adjacent to Pando, a clonal quaking aspen believed to be the largest living organism on the planet in Fish Lake National Forest (USDA Forest Service, 2022). A team of researchers were engaged in evaluating the water quality of nearby Fish Lake and needed a device that could be affixed to a dock and monitor the water surface as the level changes.

Figure 18. Water Quality Device

Fig 19. Pando (USDA Forest Service, 2022)

Conclusion

This paper details the relevance of the Concept Center to support the goals of SDG3-5, 7 and 9 through past projects completed.

By understanding the impact of the Concept Center at Weber State University to the local community, other institutions can develop their own PBL centers and further advance the United Nations SDGs in a manner that is custom to their local community. In order for the 17 goals to be achieved, academic institutions must take incremental steps and make progress in areas that are directly related to their communities. A PBL Center similar to the Concept Center is a practical way to do so and this paper demonstrates the explicit ways the goals can be accomplished through completed projects.

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