Engineering for Good: A Case of Community Driven Engineering Innovation

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ABSTRACT: *There is a culture of disengagement from social consideration in engineering disciplines. This means that first year engineering students, who arrive planning to change the world through engineering, lose this passion as they progress through the engineering curriculum. The community driven technology innovation and investment program described in this paper is an attempt to reverse this trend by fusing community engagement with the normal engineering design process. This approach differs from existing project or trip based approaches – outreach – because the focus is on local communities with which the university team forms a long-term partnership through weekly in-person meetings and community driven problem statements – engagement.*

KEYWORDS: *New product development, Economic development, community engagement*

1 PROBLEM STATEMENT

There is a culture of disengagement from social consideration in engineering disciplines (Cech, 2014). Engineering students arrive excited to make social impact, but lose this drive by graduation. This is concerning as the Organisation for Economic Cooperation and Development (OECD) lists science, technology, and innovation as keys for sustained economic development (OECD, 2000). Humanitarian Engineering largely focuses on clean water supply (Gordon et al., 2017), health and safety supplies or devices (Maxted, 2013), or renewable energy technology (Schultz, 2013) in low-resource foreign locations. This "outreach" approach relies on external experts to educate and provide solutions (Lochner, 2012). However, after a century of engineering outreach, "more people have access to mobile phones than to clean water" (Niemeier et al., 2014).

This case study applies a "community engagement" approach as part of as Community Driven Technology Innovation and Investment (CDTII) program. Engagement describes "reciprocal, collaborative relationships" in which community members are active members of the project team (Barker, 2011).

2 METHODOLOGY

The case study is organised into three phases – Engagement, Innovation, and Workforce and Economic Development. Phase 1, - Engagement, includes activities to develop community partnerships. Phase 2, Innovation, includes activities to create new technological solutions in response to community-based opportunities identified in Phase 1. Phase 3 - Workforce and Economic Development, includes activities to ensure the community can sustain economic and technological changes from Phase 2.

2.1 Phase 1 – Engagement

This phase focused on Community Driven ideas and trust building. The engineering team partnered with university-based colleagues in Rural Agriculture, Rural Economics, and the Centre for Latino/a Studies and Engagement (CL@SE) to organise a session at the 2013 Regards2Rural (R2R) conference. The R2R conference is a biennial event in which over 400 community representatives meet to exchange ideas, gain experience and receive assistance, and learn from practice or research findings. Community representatives at R2R conferences are elected or appointed local government, or county,

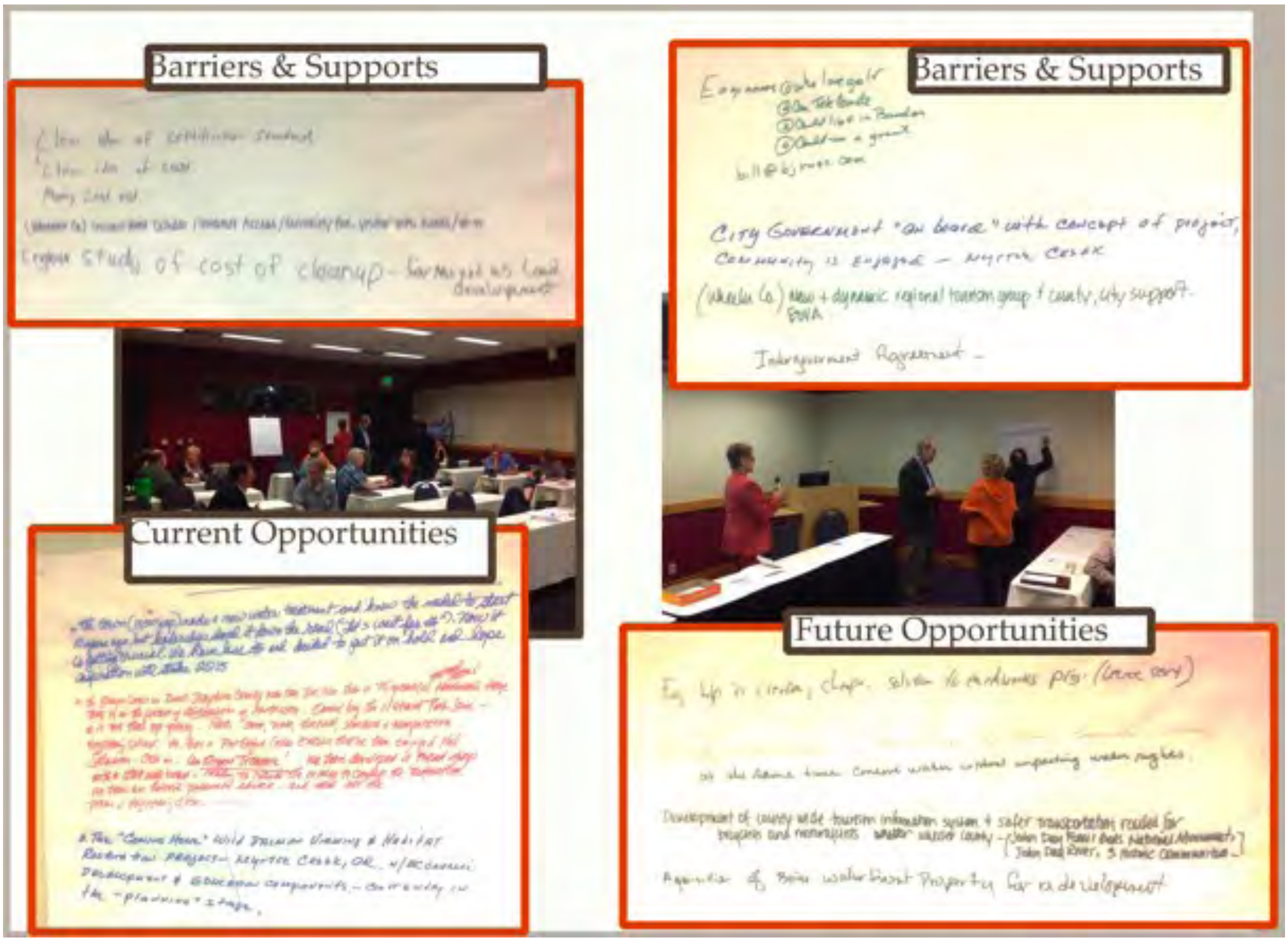

Figure 1: Brainstorm session with community representatives at Regards2Rural Conference

officials from the Pacific Northwest – Oregon, Washington, Idaho and Montana.

The R2R session objective was to explore community interest in an engineering focused approach to long-term economic development that would be driven by start-up companies. These start-ups would be formed around a technology created in response to a community need. The university team offered an investment of USD $25,000 in engineering and rural economist resourcing time for the project selected in response to the request for community proposals. This investment was made to build trust and was a down payment on a future request for communities to also invest in the potential company. Asset-based community development suggests community ownership enriches outcomes by converting community strengths (assets) into tangible inputs for development (Ennis and West, 2010).

Six projects were proposed during a brainstorm session shown in Figure 1. The team worked with community representatives at the R2R conference to evaluate projects for feasibility and technological relevance. As an example, a project that required an ecological solution for salmon management was rejected in favour of one that required a device to improve a specific production or waste management process.

2.2 Phase 2 – Innovation (Product Development)

This phase focused on the traditional engineering design process. Final year mechanical, industrial and manufacturing engineering students undergo a six-month capstone project that allows them apply their knowledge in a practical setting. More importantly, these projects expose students to project ambiguities, stakeholder demands, and unintended consequences of seemingly innocuous project decisions. Capstone projects traditionally have industrial clients who specify outcomes and can provide engineering guidance. Given the level of disengagement from social consideration. Cech (2014) describes, the CDTII team used this capstone process to engage engineering students and demonstrate practical social impacts of their engineering skills.

The projects were operated under the principle of "shared suffering," which is used to build mutual respect in virtual teams by alternating meeting times so that no single different time zone is consistently disadvantaged

Figure 2a (top left): Step 1 - Hand mix masa; Figure 2b (top right): Step 2 - Roll masa into ball; Figure 2c (middle left): Step 3 - Shape masa; Figure 2d (middle right): Step 4 - Cook sopes; Figure 2e (bottom left): Step 5 - Shape sopes into bowl; Figure 2f (bottom right): Step 6 - Garnish and serve

(Malhotra et al., 2007). In these projects, "shared suffering" is an opportunity to increase mutual learning by alternating design-meeting locations between community and university sites.

Finally, the community members are seen as active participants in the design process. This includes brainstorming, testing, and discussions about material selection. The benefit of this approach is, in part, that the engineering students solidify their learning through explanation, questioning, and re-examination of their assumptions. Research suggests that discussions, peer teaching and collaborative learning improve self-efficacy and student performance (Stump et al., 2011, Smith et al., 2011).

2.3 Phase 3 – Workforce and Economic Development

Unlike the first two phases, which focus on input actions to be taken by humanitarian engineers and community partners, Phase 3 is focused on results or long-term outcomes. Phase 3 outcomes are threefold: near, mid-to-long, and long-term outcomes. Near term outcomes include the device produced, company formed, and initial increase in employment, local income, and interest in engineering disciplines. Mid-to-long term outcomes include local and state government goals, such as work readiness and revenue initiatives like the "40-40-20 goal" in Oregon. The Oregon state "40-40-20 goal" states that by 2025, 40% of Oregon residents will have a baccalaureate degree, 40% to have an associate's degree or skills certificate, and the remaining 20% to have a high school diploma. Finally, long term success will be assessed using demographic and socio economic measures of rural versus urban trends as tests of the OECD assertion that science, technology, and related innovation are key to sustained economic development (OECD, 2000).

3 CASE STUDY

3.1 Project 1 – The Sope Maker

Three women from Monroe Oregon sought to augment family income by selling sopes – a Latin American food item – through the local Co-op. They faced three challenges: a labour intensive preparation process, inability to scale up the process, lack of standardisation in shape, quality, and content of the sopes. The current preparation process is outlined below:

Step 1: Mix the masa (dough). In this step, the ladies taught the Oregon State University (OSU) team how to hand mix the masa in a bowl to reach the desired consistency (Figure 2a).

Step 2: Roll small chunks of masa into ball shapes and set aside (Figure 2b)

Step 3: Flatten into heart shapes on a biscuit or cookie tray (Figure 2c)

Step 4: Cook on stovetop, flipping over until moderately cooked (Figure 2d)

Step 5: Remove from pan and shape edges to form a bowl – dip fingers in cool water as needed (Figure 2e)

Step 6: Place condiments and serve (Figure 2f)

This process yielded approximately 20 sopes per hour and it was identified that Step 5 posed a safety hazard as most people burnt fingers while shaping the hot sope. The engineering challenge was to create a device that would reduce labour intensiveness, produce standardised sopes at a constant rate, double the production rate, and comfortably accommodate a single operator (i.e. any device must be within reasonable lifting requirements for a single individual).

3.2 The Engineering Design Process

Phase 1: Define problem

The team answered the questions in Table 1 with minor modifications to traditional engineering design processes.

Table 1: Problem identification questions in traditional capstone versus CDTII projects

Question	Traditional Capstone Projects	CDTII Projects
Who is the customer/partner?	Partner/customer is usually an engineering company that understands engineering terms, and design constraints.	Partners were often a series of community stakeholders beyond the direct recipients of the device being created
What are the partner's needs?	Partners arrive with needs specified in engineering terminology. Problem is often a component of larger engineering project.	Partners specify business or usability goals, which the teams must convert to engineering specifications. The teams are presented with entire engineering project – no senior engineers as fail-safe.
Who is impacted by the needs and possible solutions?	Clear stakeholder delineation. Often insulated from indirect stakeholder needs.	Unclear stakeholder delineation. Direct contact with all stakeholders (e.g. city council discussions for test kitchen use, impact on families and children)
What is the nature of impact?	Normally assessed in financial and technical terms.	Assessed in socio-economic, cultural, financial, and technical terms
What are the technical aspects of the problem?	Identified with guidance from more experienced engineers.	No external/customer based engineers

Table 2: Design constraint definition questions in traditional capstone versus CDTII projects

Question	**Traditional Capstone Projects**	**CDTII Projects**
How do partner preferences influence design decisions (what conflicts exist)?	Often pre-identified and re-solved. Conflicts often financial and technical	Amorphous list of stakeholders. Unclear, multifaceted conflicts. Students work with professors and community liaison to convert preferences into engineering requirements and back into clear, non-engineering trade-offs.
Does partner appreciate how conflicts affect design decisions?	Understood without student involvement	Partners are adept at dealing with trade-offs and considering social, economic, and other implications. However, most partners are not engineers. Students must describe the physical laws that affect trade-offs between desired attributes (e.g. safe to touch) and material selection, given weight and size requirements.
Will a numeric scale for criteria importance help defuse potential tensions before brainstorming and evaluation?	Often, yes.	Works well if partners are involved in criteria development.

Phase 2: Identify constraints

The goal is to identify financial, technical, and other limitations, and assess these limitations by answering questions like those in Table 2.

Phase 3: Brainstorm alternative solutions

Traditional capstone teams often brainstorm independent of the client/partner. In this case, the community partners were involved in the brainstorming process. This was part of the engagement strategy to ensure that the community partners and the OSU team viewed each other as co-equal team members.

Phase 4: Evaluate and select viable alternatives

As with traditional project teams, the focus in this phase was ranking the alternatives generated in Phase 3 on the numeric scale generated in Phase 2.

Phase 5: Develop and test design prototypes

In this phase, the team developed prototypes and assessed results based on predetermined criteria and real time assessment by community partners. This phase, shown in Figure 3, was similar to the traditional engineering capstone experience, as the community and OSU team members had developed shared understanding of the evaluation criteria.

Phase 6: Select and implement final design

This phase was also conducted in similar fashion to the traditional capstone process. The team made modifications based on feedback from test production runs. The final sope maker (Figure 4) was introduced at an outreach and engagement symposium at the Oregon State University campus. It is important to note that the sole change to the process was made to the cooking rate. This change was in

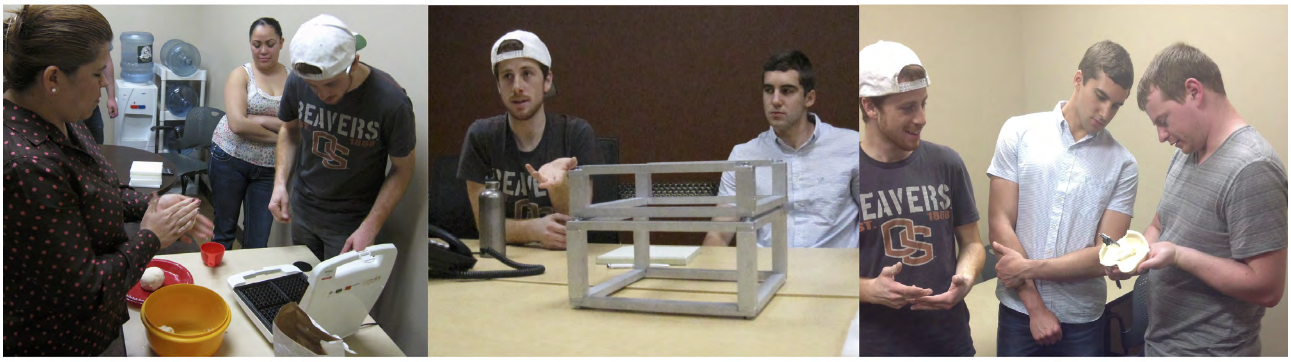

Figure 3: Prototype development and testing

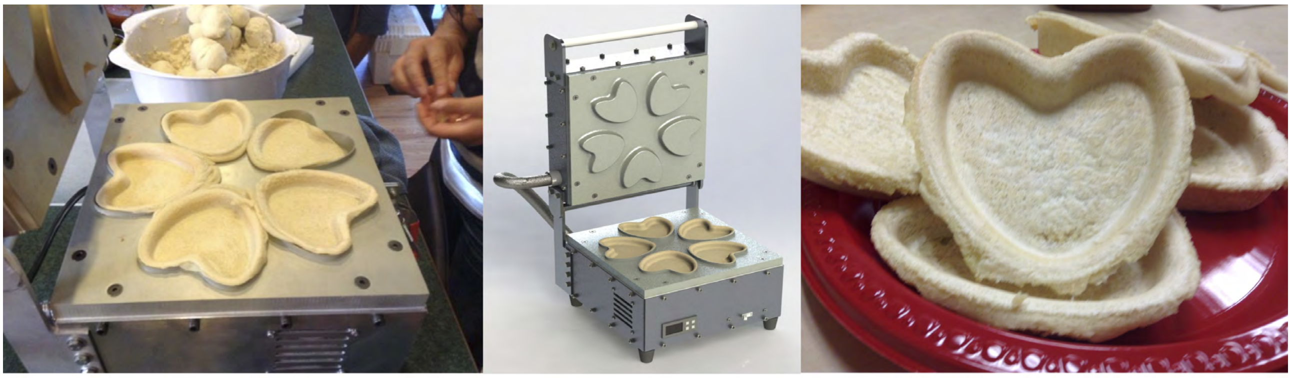

Figure 4: Final design and output

response to the community partners' desire to sell the sopes at a local co-op and at catered events. The sope mixture, which is the artisan portion of the process, did not change.

3.3 Project Outcomes

The sope project impacts can be grouped into engagement, technical innovation, and workforce and economic development categories. Community members are the appropriate evaluators in the engagement category. Feedback from our community partners is summed up in the statement by Monica Ramos, one of the three community partners, during her talk at an outreach and engagement symposium.

> "…before this, I didn't think the university had anything to offer me in my daily life…I felt respected to be viewed as an expert who was teaching people at the university something I could do well and learning from them…my son will come to OSU to become an engineer…" ~ Monica Ramos, community partner (translated from Spanish)

The technical innovation category is evaluated based on how well the engineering specifications were satisfied. The team assessed device weight, device stability (e.g. does it fall over when opened?), and statistical quality control, among others (Table 3).

The workforce and economic development category is divided into workforce and engagement sub-categories. This category is generally a lagging success indicator relative to the success indicators for the engagement and technical innovation categories. The workforce development sub-category is further divided into "university" and "community" categories. Within the university, success is assessed through changes in students' social awareness, their perceptions of the engineering profession and of engineers' social responsibility, and students' actions following participation in the CDTII program. Actions include the type of employment, volunteer activities, or graduate work students select. Workforce metrics within the community include changes in student enrolment in engineering or other higher education programs, the number of jobs created by the community-based start-up company, and the number of individuals trained for positions at the community-based start-up company.

The economic component includes the tax base, median income, migration trends, the number and nature of service-oriented businesses in the community (e.g. proportion of basic grocery and convenience stores to leisure stores). These are lagging indicators because the effects of a successful business venture will not become evident until a number of years after sustained success (e.g. profitability). Business success and expansion could lead to wage increases, higher employment and skill levels, and demand for better services and leisure activities.

There are quantitative assessments of engineering student ethical and social awareness, including the Engineering and Science Issues Test (Borenstein et al., 2010), the Engineering Professional Responsibility Assessment Tool (Canney and Bielefeldt, 2016) and the Community Service

Table 3: Select technical design criteria

Customer criteria	Result
Easily carried by one person	Spring scale weight: 19.1 kg (42 lbs), which is below the 22.7 kg (50 lbs) limit
Double the production rate	Up to 100 sopes per hour, compared to the original 20 sopes per hour production rate
Standardised product shape and thickness	Sopes were 0.635 cm (0.25 ± 0.05 inches) thick in 100 sope tests
Reliability	10% defect rate: most ill-formed sopes due to under or overfilling the measuring cup
Tip stability	Device does not fall backward when opened

Table 4: Student comments regarding social consideration

Category	Student Comments
Preconception Awareness	"I have always understood on an abstract level that an engineering degree can be used to help people." "I have thought of using my degree to building reliable energy and water sources for developing countries."
Meaningful Conflict (Dissatisfaction)	"This project opened my eyes to local struggles and local problems." "There was a discernible weight of expectation that put in to perspective the social impact engineering [could] have."
New Concept Acceptance	"The project soon became bigger than a normal design and build project. Interacting with the community demanded our teams full commitment to the success so as not to disappoint and potentially set back the community partner." "The only noticeable difference from the design process [used by other non-CDTII] was that we needed to do some translation from English to Spanish when creating the customer requirements, but other than that [the community partner] has been really understanding about the engineering design process and all the writing that is involved."
Fruitfulness	"I believe that by engaging with the group we were able to learn from them, what responsibilities and capabilities engineers have." "Learning about the impact this project will have in her life and in the life of the other lady involved in this business made me realise that through the use of engineering I can make a great impact on my community." "… we were able to deliver not only a product, but an opportunity into further STEM engagement." "I am honoured to have worked on a project that directly posed a solution to a social and economic problem."

Attitudes Scale (Shiarella et al., 2000). The research team selected qualitative analysis because the goal, at this stage of the CDTII program, is to gain in-depth understanding of the factors that drive success, change, or failure in this context. Future work on larger samples will incorporate quantitative tools. Table 4 contains statements from engineering students who participated in the project.

The research team used the conceptual change model introduced by Mirdad, Hille and Melamed (2015) to qualitatively assess workforce development based on comments made in weekly meetings and in course journals. The conceptual change model (Figure 5) is designed to guide managers or teachers through change implementation (Application Strategy) and assess learner mindset (Condition) during change projects. Stages in the "Application Strategy" are based on existing conceptual change work (Argyris and Schon, 1978, Mazur et al., 2012) that suggests individual behaviour and mindset are true drivers of large-scale change. Single-loop learners gloss over problems by identifying quick fixes or workarounds. They lack in depth knowledge about the underlying process. Double-loop learners, on the other hand, seek to understand why a problem occurred and address the root cause. The conceptual change model was designed to support managers or instructors who wish to guide learners in transition from single to double-loop.

The team assessed the statements based on the culture of disengagement described by Cech (2014). Cech's paper was based on a study of engineering students at four colleges of engineering in the United States. The results suggested that engineering students arrive for their first year with a desire to use engineering for social benefit. They gradually lose this desire as they progress through the discipline.

Figure 6 shows key words used in student discussions about the project. Words in the cloud were collected from student reflections and diary entries. To ensure the cloud reflects students' mindset, community partner names were replaced with "community partner." The team removed words, like "project" that were initially too dominant, as these words masked more meaningful third level words. Finally, plural words, such as "communities" were replaced with singular alternatives, such as "community."

"Community", "impact," "engineering," and "design," are the four most prominent words. Second-level words include "business," and "help." Third-level words include "creating," "believe," and "social." Preliminary analysis

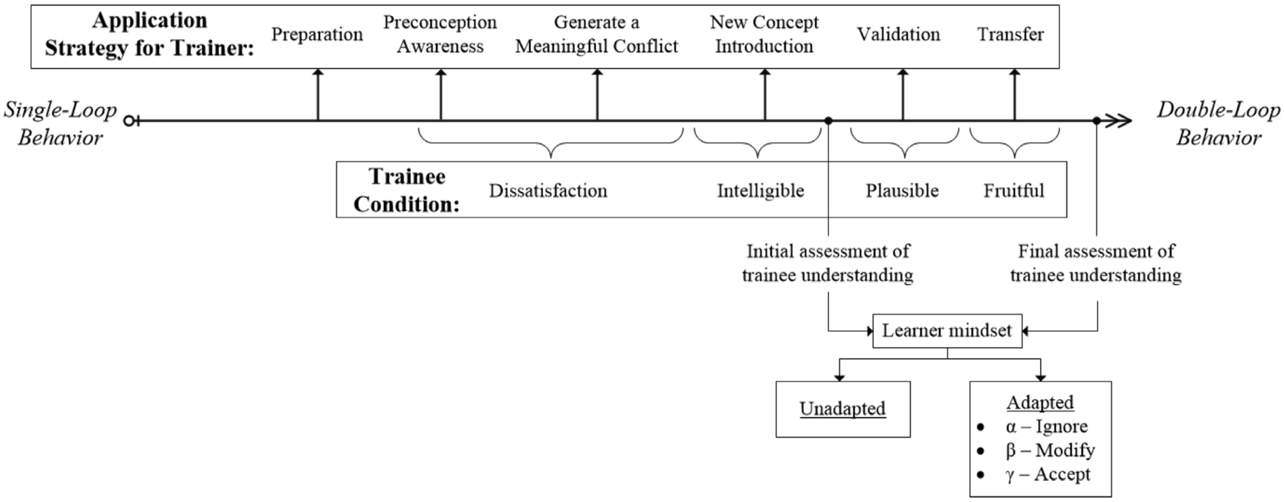

Figure 5: Conceptual change framework (Mirdad et al., 2015)

suggests students understood the socio-economic impact engineering design could have on communities.

On a personal note, one of the co-authors, who was a student in the sope project team, included the following reflection:

"I was born in Mexico and moved to United States when I was 12. I worked with my father, picking berries at the farms he supervised. He felt I was too young, but I begged him to take me to work because I wanted to help support the family. Working with the Latino community in the farms and meeting a lot of great people through my experiences, I knew I wanted to help the Latino community through the use of my career (engineering). The reason why I selected this project was because I have the connection with the

Figure 6: Word cloud from student feedback

ladies that own the sope business. From my understanding they come from a similar background to mine, and I also want to start making an impact on the Latino community with the use of engineering. I believe this project was a perfect start towards the journey of creating a positive impact on my community.

Thanks to this project, I am thinking about going to Mexico for a few months to work on projects that impact small communities. In the future, I would like to work for a company that invests in projects that impact small communities."

~Martin Alberto Cortes, fourth-year mechanical engineering student, Oregon State University.

Table 4, Figure 5, and Martin's statement suggest there might be some self-selection, which is expected at this early stage. In future iterations, the team will also assess "culture of disengagement" conceptual change among students in traditional capstone projects.

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