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Community Driven Technology Innovation and Investment: Early Reflections on Efforts to Cultivate a Culture of Engaged Engineering Scholarship at Oregon State University

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Abstract

The engineering curriculum does not often consider social aspects of engineering design and practice. This is problematic because the Organisation for Economic Co-operation and Development (OECD), lists science- and technology-based innovation as central to sustained economic development. Although land-grant Extension services translate benefits of research in agriculture, biology, and related sciences to communities, there is little emphasis on translating outcomes from engineering and technology research and innovation to communities. There is also little recognition of research of this nature in traditional promotion and tenure cases, or among traditional grant-making agencies. The Community Driven Technology Innovation and Investment (CDTII) program introduced in this paper could provide a first step to address this disconnect by developing an engagement process to help engineers forge trust-based partnerships while converting community demands into engineering design solutions and economically viable businesses. To this end, the paper contains two preliminary case studies of engineering engagement on community projects using the CDTII approach. We conclude with lessons learned and plans for future work.

Introduction

Science- and technology-based innovation is required for sustained economic development. The focus of this article is on transforming the traditional approach to engineering design education to one that places significant emphasis on social consideration. This is important because the current approach to engineering design, research, and practice is arguably disengaged from true social engagement (Cech, 2014). In the following section, we discuss the current approach to engineering design education. Next, we discuss the culture of disengagement that this approach to engineering design inadvertently fosters. Next, we highlight some of the financial and pedagogical factors that foster this culture of disengagement. Finally, we introduce the CDTII approach to engineering design that could address some of the issues with disengagement in the current engineering design education approach.

Engineering Design Education

In the traditional engineering design process, students are taught to solve problems through a seven-step iterative sequence in which they identify a problem, identify constraints, brainstorm alternative solutions, evaluate and select viable alternatives, develop and test design prototypes, select and complete final design, and implement final design. Students are generally taught through case studies or projects in clearly defined engineering environments. These environments create a system in which students learn to find right answers and understand linear design processes, but might be unable to handle ambiguity in highly amorphous situations, such as in community driven projects.

Students are asked to evaluate design alternatives by identifying evaluation criteria and assigning a weight to each evaluation criterion. As an illustration, in a team for which aesthetic quality was assigned a weight of 5, and safety was assigned a weight of 10, each of three students would evaluate each alternative generated in the brainstorming session by assigning a numerical value, or satisfaction rating (e.g. 0, absolutely does not satisfy criterion; to 5, completely satisfies criterion). The average of the students' ratings of the extent to which each alternative satisfies an evaluation criterion (e.g., safety) is then multiplied by the weight assigned to the criterion being measured (e.g., 10 for safety). The equation for this calculation is *average satisfaction rating*$_i$ X *criteria weight*$_j$, for alternative "i" and each criterion "j". Finally, the students calculate the sum products – Σ (*average satisfaction rating*$_i$ *X criteria weight*$_j$) to determine final ranks for the list of alternatives. The team selects the alternative assigned the highest sum product, or rank.

Engineers follow this system in an attempt to reduce personal bias. However, Cech (2014) argues that this approach unintentionally increases bias by discounting social criteria that are difficult to quantify. Explicit laws, technical rules, and other such guidelines are often substituted for true social engagement or consideration (Van Gorp & Van de Poel, 2008). This is problematic for a number of reasons. First, science and technology based innovation is central to sustained economic development (OECD, 2000). Second, community members perceive engineering as inapplicable to their lived experience and engineers as unconcerned with their community well-being. This leads to reduced trust and further disengagement. Third, students are attracted to, and persist in, disciplines they perceive as relevant to their daily experience (Davis & Finelli, 2007; Pintrich & Zusho, 2002; Wigfield & Eccles, 2000), so sole focus on explicit policy prescriptions in place of social engagement could reduce interest in engineering among future and current students.

There are calls for a more culturally aware approach to engineering design education and practice (Amadel, 2004) that is resilient to social and other alterations. One such call argues that the paradigm for engineering design education and practice must be transformed for design in low resource environments (Niemeier, Gombachika, & Richards-Kortum, 2014) to form a common basis for design knowledge based on fundamental principles upon which students and practitioners can make adjustments to suit their environments.

In order to discuss strategies for increasing social consideration in engineering design, it is important to first discuss some of the root cause factors that contribute to the apparent lack of social engagement in engineering design education. The focus of the following section is on a prominently held reason for the disconnect from social consideration. Next is a discussion of the pedagogical and financial incentive structures that impact social consideration in engineering design research, teaching, and practice. In the final sections, the focus is on the proposed community driven technology innovation approach and two preliminary case studies.

A Pervasive Culture of Disengagement

Previous literature emphasizes the need to create and sustain reciprocity in engaged research and practice. For engineering faculty and students, this means that community needs and criteria truly define the design process and are seen as integral to criteria selection and weighting in the alternative evaluation stage of the design process. For community members, this means institutional constraints like the Institutional Review Board (IRB) and accreditation requirements, which are difficult to address in non-academic settings (Richardson, Plummer, Barthelemy, & Cain, 2009), should be considered in the decision making process.

Cech (2014) identified three ideological pillars that reduce social engagement in engineering. The first ideological pillar, ideology of depoliticization, describes the view that any non-technical or non-quantifiable factors are unrelated to real engineering. The second pillar, technical/social dualism, describes the tendency to view technical consideration as independent of social consideration. The third pillar, meritocratic view of society, describes the tendency to view social systems as fair and objective systems in which adherence to rules leads to success.

Corporate voices are an essential and valid driver of engineering innovation. The investment and hiring opportunities that corporate voices provide support important technological advances. However, as Figure 1 illustrates, this approach potentially robs the engineering community of innovations outside the current corporate need set. Rural communities have engineering challenges, such as wastewater treatment, food production and processing, distributed energy generation, and other community revitalization projects. Under the current approach, agricultural solutions and related disciplines are the primary foci of Extension activities.

The goal of this paper is to document nascent strategies for combating the culture of disengagement in an engineering program. We highlight some of the financial and pedagogical barriers to social engagement in engineering disciplines, and introduce the CDTII program, the aim of which is to increase sociocultural engagement among engineering students.

Financial Barriers and Conflicting Incentives

The recent financial downturn poses a challenge for state government budget and benefit structures (Levine & Scorsone, 2011). The associated decline in government financial support for education, and associated search for funding through alternative sources places pressure on university-driven initiatives (Fethke, 2011). The literature is still unclear on the effects of responsible management practices, such as strategic planning, on the ability of state and municipal authorities to create financially resilient systems (Jimenez, 2013).

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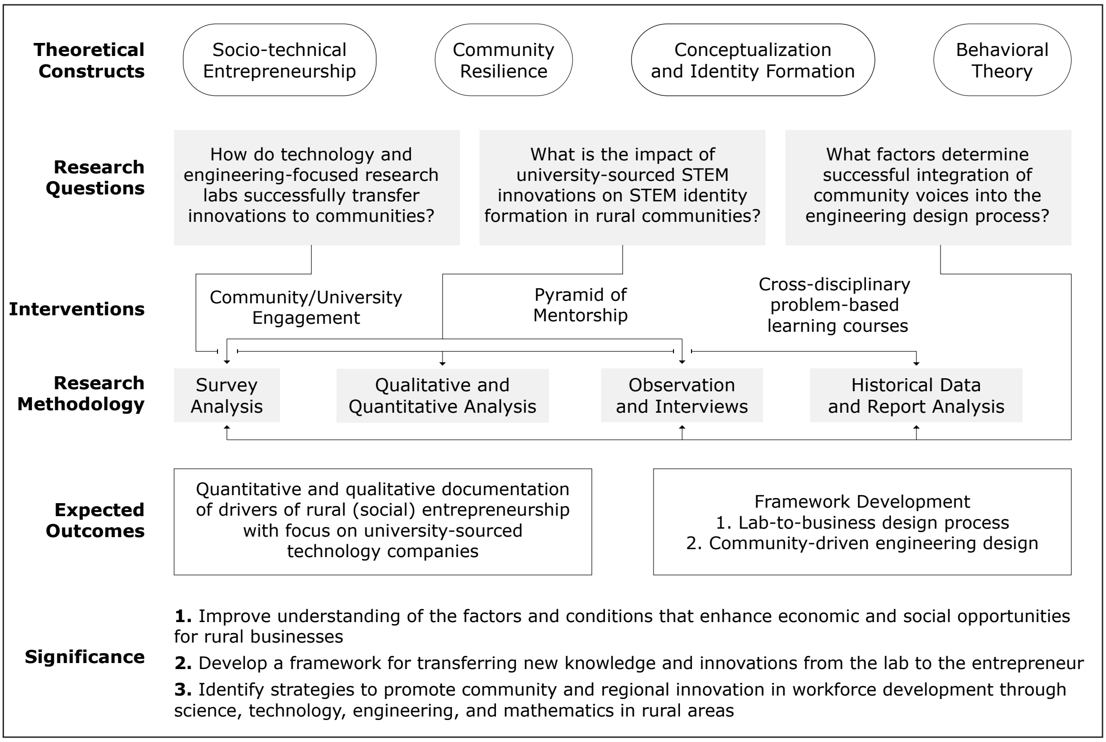
Figure 1. Overview to Extending Land-Grant Mission



State governments have created goals, such as the 40-40-20 goal in Oregon. This goal calls for 40 percent of Oregonians, by 2025, to have a baccalaureate degree or higher, 40 percent to have an associate degree or higher, and for the remaining 20 percent to have completed high school. In resource poor, opportunity/idea rich environments, university researchers must allocate their time and resources in view of returns, such as tenure and associated requirements (e.g. funding, students, and publications).

There is an important role for engineering research and practice in developing and sustaining a vibrant, highly competitive economy in line with the OECD findings and state government goals. However, funding requirements increasingly outweigh declining state budget allocations for education. As a result, engineering innovation is increasingly dependent on, and responsive to, corporate voices. While corporate voices play an important role in ensuring a vibrant society, sole focus on response to corporate voices comes at the expense of community benefit. This is especially problematic in land-grant institutions, where community benefit is central to the mission of the institution. In addition to financial challenges, there are apparent pedagogical limitations to the degree of social consideration or engagement in engineering disciplines.

Pedagogical Limitations

The engineering body of knowledge is arguably prescriptive and deterministic. Prescription, in engineering, is necessary because the subject matter is, by nature, deterministic. There are physical laws that are not open to interpretation, or non-empirical modification; the effects of gravity and Newton's laws are cases in point. Cech (2014) describes these pillars of engineering education and practice as necessary but detrimental to social exposure. Engineering programs are also subject to review by the Accreditation Board for Engineering and Technology (ABET) that requires delivery of specific content in order to maintain accreditation.

Engineering students are increasingly involved in team-based assignments, components of education in the humanities, and other aspects of a broad core curriculum outside the engineering discipline. It is possible that these courses are seen as less valuable fillers in the periphery of normal engineering coursework. However, most engineering students undergo a capstone course in which they are expected to incorporate lessons from their entire program of study into the design of a product, system, or service. These courses rely on the seven-step engineering design process previously mentioned. Table 1 is a preliminary mapping of the engineering design process to questions that foster engagement.

Table 1. Community-Centric Translation of the Engineering Design Process

Engineering Design Process	Questions to Foster Community Involvement
1. Identify the problem	Who is the partner? What are the partner's needs? Who is impacted? What is the nature of impact? What are the technical aspects of the problem?
2. Identify constraints	What are partner preferences, incentives, and limitations? What conflicts exist? How do these conflicts influence design decisions? What are the non-negotiable engineering design constraints? Does partner understand these constraints and the conversion to design criteria? Will a numeric scale for criteria importance help defuse potential tensions in advance of brainstorming and evaluation?
3. Brainstorm alternative solutions	What are partner ideas for a solution? What has been tried? What lessons have been learned from previous attempts?
4. Evaluate and select viable alternatives	How do alternatives from Step 3 rank on the scale developed in Step 2? Is there a clear selection? What modifications are needed to the criteria in Step 2, to the list in Step 3, or to the winning selections (in the event of a tie) to address relevant concerns?
5. Develop and test design prototypes	Are partners involved in the development and testing process? Is the process sufficiently representative of actual operation to allow effective partner input?
6. Select and complete final design	What modifications are needed? Are expectations for final performance clear and accepted by all partners?
7. Implement final design	What follow up plans are needed to ensure proper integration and use? Are there training, access, and other issues to address? What infrastructure is needed to sustain outcomes?

This process gives ample room for community involvement. There is a need for revisions to the manner in which engineering design is taught. This paper contains a description of preliminary work at Oregon State University aimed at cultivating a culture of socially aware, context relevant engineering design. Context relevant engineering design seeks to address the triple bottom line of social, environmental, and financial profit. The aim of the CDTII program is threefold: engagement, innovation, and workforce and economic development.

CDTII as a Vehicle for Engaged Engineering

To address the challenges of poor social engagement in engineering design, a cross-disciplinary group at Oregon State created a three-pronged program of engagement, innovation, and economic development to investigate the effect of an engaged approach to engineering design on engineering student perceptions of engineering and the role of engineers in society.

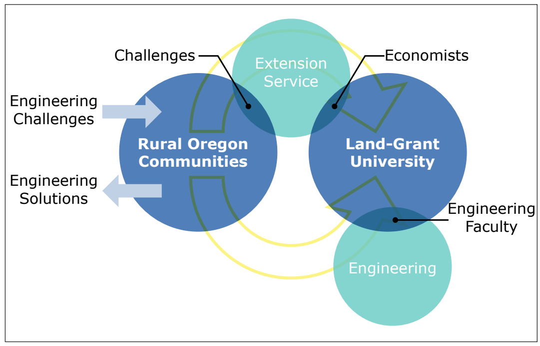
The goal of the program is to extend the land-grant mission to engineering and technology-based innovations. Specifically, the CDTII triple aim is to build on the existing engagement infrastructure (Open Campus, the Center for Latino/a Studies and Engagement, Rural Studies, and others) to gain social capital for effective engineering in direct social contexts, as opposed to the indirect social contact of the current design process. Figure 1 is an overview of the multi-faceted approach to extending the land-grant mission to engineering and technology in a manner that ensures long-term community benefit, while improving engineering education.

In this paper, the focus is on introducing the approach and highlighting experiences from the first two preliminary project runs. This discussion is important for land-grant universities because the ability to translate products of university-based research to practical benefit for rural communities is a central tenet of the land-grant mission. Extension services traditionally excel at this translation in fields such as science and agriculture. Given the OECD designation of technology-based innovation as key to sustained economic development, there is a need for frameworks that broaden the Extension mission to encompass products of engineering and technology research. The remainder of this paper provides an outline of attempts to develop such a framework through CDTII.

Demographic and infrastructural challenges often make rural communities less attractive to for-profit organizations. Where incentives, like tax breaks, are used to attract companies, there is a larger threat of socio-economic displacement of indigenes, and of eventual relocation of companies when incentives expire, or when a better deal is offered elsewhere. Using the Asset Based Community Development approach to technology focused social entrepreneurship, we seek to investigate (1) best practices for transferring innovations from engineering research labs to rural entrepreneurs, (2) factors that determine successful integration of community voices into the engineering design process, and (3) the impact of university sourced engineering innovation on engineering identity formation. The investigation of identity formation is twofold: conceptualization of, and attraction to, engineering in rural communities, and conceptualization of the role of engineering in society among current engineering students.

An ecosystem in which university and community conceptualization of engineering as an important facet of socio-technical benefit can improve community resilience. Here, resilience is the ability of a community to "bounce back" from a socio-economic shock, such as the decline of the timber industry in Oregon. Figure 2 is an outline of the CDTII approach in which socially engaged engineering design can help promote technology-driven rural entrepreneurship, highlight the social benefits of engineering, and increase the long term attainment of the 40-40-20 goal. This ecosystem contributes to this goal because research suggests that demonstration of social benefit is a strong determinant of attraction to and retention in engineering and STEM disciplines.

Figure 2. Ecosystem of Community/University Partnerships



Overview of Preliminary Projects

The CDTII team conducted two pilot community projects (Project 1 and Project 2) during the 2014–2015 school year. Each project was staffed by a team of three final-year engineering students, who completed work on the CDTII project as part of the requirements for their capstone course. The capstone course is a comprehensive project-based course that all engineering students must complete at the end of their four-year program. The course gives students an opportunity to demonstrate competence—develop engineering identity (Carlone & Johnson, 2007)—by solving a real-world problem with minimal help from faculty. Projects are generally industry based. The three students on Project 1 were from the same department as the lead author. The second author was one of these three students. The students on Project 2 were from a different engineering department at Oregon State. All the members of both teams were engineering students. All engineering students receive similar training, but discipline specific specialization might result in slight variations in problem solving approaches. However, the broad approach to problem solving should be largely similar, if not identical.

Project 1 was initiated in partnership with a group of rural entrepreneurs from a neighboring county. The goal was to design a food-processing machine that could make Sopes (a traditional Mexican food item). The entrepreneurs—three Latina women—planned to start a company that would sell Sopes to a local co-op. The team was to develop a system that would enable them to produce a standardized product at a rapid pace. Standardization was important because aesthetics is important in grocery sales. Speed was important because the entrepreneurs had day jobs on which their families depended. Extension officers affiliated with "Office A" facilitated this project connection.

Project 2 was also initiated in partnership with a community intrapreneur at a neighboring county office. The goal was to design a remote kiosk that tourists could use to charge phones and view interactive maps. The device would improve tourism in the county, reduce conflicts between tourists and farmers (through notifications on the dynamic mapping system), and enable the county to share real time information, especially important in public emergency situations. Extension officers affiliated with "Office B" facilitated this connection.

Aim 1: Engagement

There is a level of trust and relationship building that is required for effective engaged research that is not necessarily needed for outreach focused activities. Although the focus is on change management in organizations, this concept of trust building and "buy-in" is increasingly common in engineering research and practice. For instance, the literature suggests that process improvement initiatives, such as lean manufacturing implementation, are faced with a high failure rate—over 70% (Blanchard, 2007), because the focus is largely on tool application (outreach mindset) instead of cultural transformation, which is engaged, painstaking, and potentially transformative. To this end, there is a growing body of knowledge that addresses approaches for engineering managers to effectively

[1] "Going to Gemba" is a process improvement term used to remind engineers of the high value of firsthand knowledge based on their daily experience with Gemba: "the actual place" where work gets done.

communicate goals with team members (see Farris, Van Aken, Doolen, & Worley, 2008), and develop context specific training programs (see Wiseman, Eseonu, & Doolen, 2014). In lean process improvement, this approach of seeking to truly understand the problem through immersion before proffering solutions is called "Going to Gemba."[1]

The goal of the engagement aim is to "go to Gemba" in an attempt to include community voices in the conceptualization and design phases of the engineering design and innovation process. The existing approach in engineering design often requires community adaption to an existing design. In this mindset, designers solicit feedback from community members and the general public after preliminary or final design. By requiring students to weigh community inputs as important design requirements, the CDTII approach could enhance understanding of the impact of technology in these communities. This understanding empowers engineers to engage with community partners, while enabling community partners to articulate opportunities for technology innovation.

Trust is an essential component of effective university-community partnerships, especially given the power disparity in these relationships (Fisher, Fabricant, & Simmons, 2004). In keeping with recent efforts at engaged scholarship (Archer-Kuhn & Grant, 2014), the CDTII approach is to use power for collaboration and to create spaces for bilateral learning. To this end, the CDTII team applies the transformational relationship approach (Enos & Morton, 2003; Stewart & Alrutz, 2012) outlined in Table 2.

The Project 1 team held a kick-off meeting in the community library so that the rural entrepreneurs met the team in a setting that was familiar to them. This also signified equal empowerment. One of the students (the co-author) spoke Italian, which he sought to convert to Spanish. The entrepreneurs recognized this as a sign of respect and seemed to open up to him. The goal of the kick-off meeting was to discuss the problem statement that had been previously provided by the rural entrepreneurs and to discuss the engineering design process. The rural entrepreneurs left the meeting excited about the project after setting dates for campus visits.

During the first campus visit, the rural entrepreneurs were invited to teach the engineers to make Sopes in the university test kitchen. This was an important step because the community members—women from an ethnic minority who had never been at the university and were uncomfortable communicating exclusively in English—were seen as experts who were invited to impart their knowledge. This turned out to be a very important bonding session, as the entire team kneaded dough on instructions from the women, placed the dough on pans, prepared the hot Sopes (while rushing to dip fingers in cool water), and eventually shared a meal together.

Project meetings were then alternated between the community and campus. This arrangement was selected to demonstrate the desire of the CDTII team for equal partnership, to provide students and other researchers an understanding of the potential impact of engineering design, and to identify and seek to understand community values and goals. University based meetings were intended to familiarize community members with the university, recognize them as competent experts on their recipes and on the use of the technology being designed, based on the competency, performance, and recognition identity triad (Carlone & Johnson, 2007). Community-based meetings were attended by the community partners, the engineering students, CDTII faculty, the graduate students in charge of daily supervision of the project team, and the instructor for the capstone course. Campus based meetings were

Table 2. The Transformational Relationship Approach

	Project 1	Project 2
Number of students	3	3
College	Engineering	Engineering
Subject Matter	Design of food processing machine	Design of an interactive, remote information and phone charging kiosk
Supervision	Direct CoTII authority over student grades	Advisory CoTII authority over student grades
Community Engagement	Weekly meetings	Intermittent due to conflicting schedules
Client	Three women from a rural community	County planning department (work was done for use on rural bike and hiking trails)

attended primarily by community partners, the engineering students, and two CDTII faculty from engineering and liberal arts.

Project 2 was less successful in true engagement. The team invited the client to a kick-off meeting on campus and was unable to travel to the client location due to scheduling conflicts. The team was technically sound and understood the client requirements as written. However, there appeared to be less commitment to the client beyond the confines of the capstone course. This was also a considerably busy term for members of the Project 2 team who needed to liaise with CDTII staff outside their home department—albeit within the College of Engineering—and manage a busy job interview season alongside normal coursework. Table 3 contains details of the two engineering student teams that worked on these projects.

Implementation of Aim 1

Aim 2: Innovation

In the innovation portion of CDTII projects, engineering student teams create new engineering designs in a manner that directly addresses the needs of the community. The key difference from traditional engineering innovation is that the explicit focus is on community benefit. While this often includes the ability to operate a successful business, the team seeks to take the social entrepreneurship view to innovation.

Traditional university research and commercialization often leads to revolutionary technology and products such as the Gatorade drinks at the University of Florida, cottonseed technology at Texas Tech, and nanotechnology for distributed energy generation, cardiovascular remedies, and home dialysis, at Oregon State.

Table 3 illustrates the current scenario for engineering innovations. The goal of Projects 1 and 2 was to help us better understand how to extend the engineering innovation-to-commercialization framework beyond the current focus on industry partners to include community partnerships. Some of these lessons are discussed later in this article.

Aim 3: Economic and Workforce Development

The focus of the third aim, workforce and economic development, is on creating conditions for sustainable long-term economic growth in the community. This aim encompasses economic development in the form of social entrepreneurship, short term employee training to fill newly created jobs, and long term training of children from the communities in modified programs aimed at developing rural entrepreneurs who have the social capital and investment to return to these communities. STEM attraction and retention is a major thrust of the third aim. The literature suggests nontraditional students are attracted to, and stay in, STEM disciplines if they can see the social benefit of STEM products.

Figure 2 illustrates the envisioned ecosystem of community/university partnership for technical innovation. Trust is essential for university/community partnerships. The existing Extension service infrastructure plays an important role in training engineers to interpret community goals, and in setting community expectations of the engagement program.

Table 3. CDTII Approach to Ensuring Transformational Partnership, adapted from Enos & Morton, 2003; Stewart & Alrutz, 2012.

Transformative Relationship Criteria	CDTII Interpretation
Focused on ends beyond utilitarian goals	The technology and potential business is a by-product of the larger learning, socio-economic, and cultural growth.
Positively alters group identity and larger definition of community	Students and partners belong to a unified project team. The fusion of communities (academic and geographic) is aimed at altering conceptualization of place and fit for all partners.
Pushes institutional boundaries by examining goals	Core to the CDTII program is the belief that students at a land grant university should be decidedly different from their counterparts at other universities in terms of their understanding of their place and role in larger society, knowledge of the tools their training provides to impact socio-economic change in corporations, and in local and global communities.
Focused on ends beyond utilitarian goals	Community and university partners drive the engineering design process in CDTII.

Offices, such as Open Campus and the Center for Latino/a Studies and Engagement at Oregon State played this role in the pilot projects.

Lessons Learned

The students in Project 1 developed a prototype that the entrepreneurs now use. Several factors appear to have contributed to the outcome observed in Project 1. Students involved in Project 1 were under the direct supervision of CDTII faculty. This project also had a designated liaison from "Office A." The liaison worked with the team of students and CDTII faculty to set up regular meetings with the rural entrepreneurs. "Office A" sought to alternate meeting locations with the aim of building trust and empowering the entrepreneurs as subject matter experts in what was a detailed, and otherwise intimidating, engineering design process. Students gave presentations to the entrepreneurs in their native language and went through several in-person feedback iterations. The students developed a sense of ownership, expressed in statements by one of the students: "Other teams develop products for a company in which several engineers can tweak and improve on the prototype, but in this case, we are 'it'. We have to make this work for the ladies."

Project 2 was less successful than Project 1. Here are some lessons learned from the outcome of Project 2:

1. Responsibility-authority parity: Game theory suggests that the human brain is wired to act in ways that preserve and maximize personal gain. Students are, thus, conditioned to prioritize actions that directly impact their grades and chances of employment upon graduation. Due to the structure of university courses and ABET accreditation, CDTII faculty served as advisors with no input on student grades. This complicated deliverables and broader quality issues.
2. Student self-selection: Students in Project 1 selected their project from a list. Project 2 was assigned the CDTII project. It is possible that there is a level of prior social exposure, and engagement, that drives student interest in work of this nature. Future projects will rely on self selection as we seek to incorporate social engagement strategies into the engineering curriculum and design process.
3. Extension personnel: The envisioned ecosystem in Figure 2 relies on the Extension service as an important "translator" to facilitate partnership between the engineering and community teams. Project 1 relied on a dedicated Extension liaison from "Office A," which facilitated community relationships and highlighted best practices for presentations and other community forums. Personnel changes in "Office B" meant Project 2 did not have an Extension liaison. Students communicated with the client by email and in an on campus meeting at the beginning of the project. The team was unable to visit the client due to time constraints.

Conclusion and Future Work

The CDTII project seeks to include engineering students and researchers in the function of the land-grant institution. To do this, a cross disciplinary team of engineering, liberal arts, and Extension faculty worked with two teams of final-year engineering students on a nontraditional engineering design project. The goal of this approach was to (a) conduct "proof of concept" tests in a low-risk environment, (b) identify supports and barriers to this form of community/university engagement, (c) help us better understand how to partner with community members to achieve shared goals, given the perceived power differential (Fisher et al., 2004), and (d) explore the modification of the current technology commercialization model, to include social entrepreneurship.

Additional teams are being recruited through the capstone pipeline, with focus on the departments in which CDTII faculty members have direct grading authority. The team will continue to investigate the community driven technology innovation by (a) continuing engagement with current rural entrepreneurs, (b) creating non-rural partnerships to increase our understanding of the social entrepreneurship focus by mirroring the existing technology commercialization framework, and (c) conducting interviews with the students and community partners at various points during the project to identify personal factors that affect the outcomes we observe.

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