122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #13876

Not engineering to help but learning to (un)learn: Integrating research and teaching on epistemologies of technology design at the margins

Dr. Prashant Rajan, Iowa State University

Prashant Rajan is an Adjunct Assistant Professor in the Department of English and the Communication Studies Program at Iowa State University. He has a B. Eng. in polymer engineering from Pune University, an M.S. in materials science and engineering from the University of Cinainnati, and a Ph.D.in Organizational Communication with Ph. D. minors in research methods and critical-cultural theories from Purdue University. He is interested in: (a) learning about strategies to integrate conversations on compassion, empathy and social justice issues in the engineering education, (b) studying how information and communication technologies may be designed and implemented to improve food access, (c) researching methods for documenting and adding value to indigenous knowledge and grassroots innovations, and, (d) encouraging engagement between students, faculty and grassroots designers located in rural, semi-urban and urban communities. He can be contacted by email at prajan@iastate.edu.

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Abstract

Locating engineering education projects in sites occupied by marginalized communities and populations serves primarily to reinforce the misapprehension that the inhabitants of such sites are illiterate, inept, incapable and therefore in need of aid or assistance from researchers, faculty and students. Drawing on the emerging literature on engineering education and social justice, I examine the stated objectives, content, duration, and outcomes of exemplar projects to develop a critique of the epistemological and axiological assumptions and privileges of educators, scholars and students who engage with communities that exist on the margins. I argue that as students, teachers, and researchers, we equate the minds of those who occupy economic and social margins with the possession of marginal intellect when we set out to help or aid them without recognizing the validity of and valorizing their ways of knowing. Learning how members of socially and economically marginalized communities apply their minds, mouths, hands and feet to solve locally occurring problems may help us interrogate our scholarly, pedagogical, and ethical objectives in a more reflexive manner.

Drawing on ethnographic research and writing carried out across 11 months across 25 rural, semi-urban, and urban communities in India and the United States, I demonstrate how we may begin to recognize and relinquish our positions of privilege by observing local epistemologies of technology design while apprenticing the otherwise marginalized as they go about solving everyday problems. Such local epistemologies are articulated through knowledge practices that are communicative, relational and situated in local social and material contexts. I contend that our task is to learn from those who we otherwise imagine as being in need of the knowledge, skills and expertise located in academe.

I employed a combination of open-ended interviews, guided conversations, and participant-observation of individual artisans, farmers, entrepreneurs, and their family members, friends and local collaborators to learn about the ways in which those who lack access to formal education or formal institutional support have developed novel, affordable technological solutions for problems in their local communities. My analysis suggests that individuals who develop technological innovations at the margins are motivated by a perceived responsibility toward their local communities. Such *grassroots innovators* articulate this perceived responsibility by remaining sanguine about the imitation of their designs by others. Their openness in sharing design-related

knowledge is associated with the adoption of an empathic design process in which innovators leverage their social and material embeddedness in local communities to observe and reflect on users' technology-related behavior in naturalistic settings. Grassroots innovators engage with human needs in specific geographical, economic, social, and cultural contexts and embody the potential for knowledge-rich, resource-poor communities to develop successful indigenous solutions to local problems. Grassroots innovations represent a community-based and user-driven model of technology design based on empathy, sustainability and social responsibility that problematize rational, economic models of competitive innovation for profit that are prevalent in the literature and industry. Finally, I outline my efforts over the past two years to incorporate these findings into the syllabi and classes I teach to engineering majors studying a required course technical communication. This report of my pedagogical efforts is provided so that colleagues who share an interest in social justice may critique and improve my efforts at achieving coherent and sustainable pedagogical translations of my research on technology design at the grassroots. As engineering education scholarship develops its transnational agenda, I also offer this research design, my findings, and pedagogical efforts as points of entry for scholars and educators to reconfigure the relationship between teachers, learners, and the contexts in which their interactions are situated.

Introduction

Engineering education scholarship and practice distinguishes between students, faculty and scholars, and, the communities they seek to serve by drawing on analytical 'dimensions-of-difference' to construct inhabitants of the 'Global South' as marginalized communities and populations.[1] However, such differences are reported in curricular and scholarly documents as social, material, and cultural challenges to the conduct of teaching and research in the field.

Locating engineering education projects in sites occupied by marginalized communities and populations serves primarily to reinforce the misapprehension that the inhabitants of such sites are illiterate, inept, incapable and therefore in need of aid or assistance from researchers, faculty and students. Drawing on the emerging literature on engineering education and social justice, *I summarize trends in engineering-to-help (ETH) activities and examine the stated objectives, content, duration, and outcomes of two exemplar student ETH projects*. My objective is *to develop a critique of the epistemological and axiological assumptions and privileges of educators, scholars and students who engage with communities that exist on the margins*. Specifically, I note the interventionist and ahistorical nature of the projects analyzed, and draw attention to the lack of local design epistemologies in humanitarian engineering scholarship and practice.

I argue that as students, teachers, and researchers, we equate the minds of those who occupy economic and social margins with the possession of marginal intellect when we set out to help or aid them without recognizing the validity of and valorizing their ways of knowing. I provide three exemplar grassroots practices of seeking feedback, perceiving needs and problems, and organizing instrumental assistance and cooperation. Learning how members of socially and economically marginalized communities apply their minds, mouths, hands and feet to solve locally occurring problems may help us interrogate our scholarly, pedagogical, and ethical objectives in a more reflexive manner. I perform such an interrogation of two student projects listed on the Engineers for a Sustainable World's 2015 Sustainable Homes initiative.

Members of grassroots communities frequently engage in designing and developing novel technological solutions for locally occurring problems. Such novel technologies, which initially emerge through the independent efforts of individuals and groups from communities operating at the grassroots level of organization, may be referred to as *grassroots innovations*.[1] Grassroots innovations may serve as vital points of entry for researchers who are interested in examining the connections between local design practices, norms and values, and the material environment.[2]

I report learnings obtained from innovative artisans, agriculturists, and entrepreneurs who are collaborating with the Honey Bee Network (HBN) – a local, national and global network of grassroots community members, agriculturists, scholars, policy makers, entrepreneurs and non-governmental organizations (NGOs) engaged in organizing grassroots community members and holders of traditional knowledge. A combination of interviews, guided conversations, and ethnographic methods of observation and participation were employed to study practices underlying the design, development, and use of technological innovations across seven rural, semi-urban, and urban communities in Gujarat state. Here, I focus upon the communicative interactions between grassroots community members, their collaborators, and their social and

physical environment during the design, development and use of grassroots technological innovations.

I present that innovative grassroots technologies are organized around specific epistemic practices associated with articulating and sharing knowledge. Such epistemic practices are simultaneously conceptual tools and observable phenomena.[3] While scholars have expended considerable time and effort studying subject-object relations in formal science, less work has taken on the task of understanding how objects of knowing remain incomplete and emergent in their partial nature outside of scientific laboratories.

Directing our attention to grassroots community members, we can ask: *How can incompleteness and emergent attainment of material form be understood by observing the epistemic practices of grassroots community members*? As this submission demonstrates, grassroots community members employ epistemic practices that generate representations that are always in physical and functional approximation to the expected use. Furthermore, in reiterating rather than eliminating lack, these practices suggest that grassroots community members' employ epistemic practices that reflect the social and material environment in which grassroots innovations are designed.

The epistemic practices of grassroots community members may be conceptualized as routine or creative practice, and are representative of their ability to negotiate incompleteness or lack in the objects they design and use, and the environment where such design is carried out. Such incompleteness helps grassroots community members extend routine practice in new directions. Grassroots community members express the need for innovative design in terms of a perceived responsibility toward their local communities. Grassroots technologies may be understood as incomplete artifacts whose embodied design is based upon reflexive, empathic naturalistic observations of user needs and material constraints and availabilities, and the incorporation of such observations into broad tolerances that are continuously refined as the design is adapted for different use cases.

Drawing on ethnographic research and writing carried out across 11 months across 25 rural, semi-urban, and urban communities in India and the United States, I demonstrate how I may begin to recognize and relinquish our positions of privilege by observing local epistemologies of technology design while apprenticing the otherwise marginalized as they go about solving everyday problems. Such local epistemologies are articulated through knowledge practices that are communicative, relational and situated in local social and material contexts. I contend that our task is to learn from those who I otherwise imagine as being in need of the knowledge, skills and expertise located in academe.

I employed a combination of open-ended interviews, guided conversations, and participant-observation of individual artisans, farmers, entrepreneurs, and their family members, friends and local collaborators to learn about the ways in which those who lack access to formal education or formal institutional support have developed novel, affordable technological solutions for problems in their local communities. Our analysis suggests that individuals who develop technological innovations at the margins are motivated by a perceived responsibility toward their local communities. Such *grassroots community members* articulate this perceived responsibility

by remaining sanguine about the imitation of their designs by others. Their openness in sharing design-related knowledge is associated with the adoption of an empathic design process in which grassroots community members leverage their social and material embeddedness in local communities to observe and reflect on users' technology-related behavior in naturalistic settings. Grassroots community members engage with human needs in specific geographical, economic, social, and cultural contexts and embody the potential for knowledge-rich, resource-poor communities to develop successful indigenous solutions to local problems. Grassroots innovations represent a community-based and user-driven model of technology design based on empathy, sustainability and social responsibility that problematize rational, economic models of competitive innovation for profit that are prevalent in the literature and industry. Finally, I outline my efforts over the past two years to incorporate these findings into the syllabi and classes I teach to engineering and liberal arts majors in technical communication, technology and culture, and, leadership and teamwork. This outline of my pedagogical efforts is provided so that colleagues who share an interest in social justice may critique and improve my efforts at achieving coherent and sustainable pedagogical translations of my research on technology design at the grassroots. As engineering education scholarship develops its transnational agenda, I also offer this research design, my findings, and pedagogical efforts as points of entry for scholars and educators to reconfigure the relationship between teachers, learners, and the contexts in which their interactions are situated.

Background: Engineering to help (ETH) trends

Trends in the internationalization of service learning in engineering education suggest a burgeoning interest among students, universities and professional organizations in tackling issues of social and economic development.[4,5,6,7,8] Diverse campus-based and professional programs having labels including humanitarian engineering, service learning, sustainable development, social entrepreneurship are engaging in "engineering to help" (ETH) activities because they share the objective of helping communities "in need".[8] ETH projects provide students, primarily engineering majors from North America and Europe with the opportunity to spend a short time in developing nations with the objective of solving a local problem or understanding local contexts of technology use. The engineering education community carries forward this mandate for achieving socioeconomic development in global settings and local contexts while retaining curriculum-centric goals, industry-focused interests and media-sensitive practices.[8] Engineering education scholars[4,8] have contextualized the spurt in ETH activities by discussing the influence of changes in ABET criteria, increased attrition in corporations that traditionally employ engineers, and increasing media coverage of environmental and humanitarian crises and issues. Valid concerns have been raised regarding the value of interventionist projects that are short-term (averaging between four to eight weeks) and ahistorical in their approach to stating the engineering problem in simplistic terms that homogenize intervention sites and their inhabitants. Such projects are often motivated by a need: (a) to serve industry sustainability mandates and social responsibility interests and, (b) to achieve curricular and accreditation metrics. Engineering educators and students who aspire to help those in need are better placed if they begin to interrogate their own motivations to "help" and their assumptions regarding the sites, populations and communities they seek to work with.

A common characteristic of ETH activities has been the emphasis on devising and introducing technology-based interventions to communities in developing nations. Such interventionist forms of research focused on solving locally occurring problems through the introduction of technologies that produce measurable improvements in indicators of social and economic development among users who constitute members of the local populace. A fundamental analytical distinction between researchers and participants is obtained by recognizing the difference between the socioeconomic status of students, faculty and the communities and populations where ETH projects are situated. The articulation of economic differences is associated with the explication of social, cultural and geographical differences between the "helpers" and the "helped". Such dimensions-of-difference are indicative of important assumptions regarding the ability of users to participate in processes of knowledge creation and sharing. These assumptions are framed as methodological and practical challenges to be faced while working with economically marginalized communities.

Literacy remains a primary dimension-of-difference between communities and ETH project teams. In addition to literacy, scholars discuss a variety of experiences related to the physical, cultural and technical contexts in which development-oriented research is carried out. Technical challenges include the failure of equipment due to environmental conditions such as humidity, heat, dirt and dust, frequent power outages and fluctuations in voltage supply, logistical constraints associated with transporting, shipping and producing equipment locally, and unexpected natural disasters and crises. In addition, a number of cultural challenges are presented including the prevalence of crime, corruption, and illiteracy, difficulty in training, and compensating and retaining staff who work on ETH projects when students an faculty have returned from their sojourns. Projects may also report the need to be sensitive toward gender roles and norms when operating within socially "conservative" communities.

Most ETH projects operate within the interventionist paradigm, the purpose behind understanding contexts in which field research occurs is explicitly linked to the objective of deriving concrete, actionable implications for interventionist design. Thus, a concern with the geographical, social and cultural contexts of users is unapologetically focused on extracting design constraints. Dimensions-of-difference become methodological challenges rather than opportunities for reflection and learning.

Researchers must learn to negotiate their roles as outsiders to local communities by grounding themselves in established practices of knowing and sharing knowledge. A first step in increasing reflexivity is to acknowledge that local communities may possess epistemologies of design that they enact in their everyday lives. Members of communities are frequently engaged in designing and developing novel technological solutions for locally occurring problem. Such novel technologies which address local needs and emerge through the efforts of individuals and communities operating at the grassroots level of organization may serve as vital points of entry for researchers who are interested in examining how engineering practice intersect with local value systems.

Engineering to Help (ETH): Engineers for a Sustainable World (ESW)

Engineers for a Sustainable World emerged from a master's project incubated at Cornell University's Center for Transformative Action. The first chapters were formed at Cornell and Pennsylvania State University in spring 2002. Later that year, chapters were formed at other elite universities further west including Northwestern, Stanford, Caltech, and UC-Berkeley. It operates as a non-profit organization. It is a shared platform for connecting individuals representing a network of 37 campus-based and three professional "autonomous" chapters located in the US and Canada. Its membership of ~1000 members is concentrated in elite university campuses across the US and Canada.

ESW underwent significant restructuring post-2008, including the departure of its founder and the relocation of its national office from Ithaca, NY at Cornell to Oakland, CA. Subsequent relocations shifted ESW offices to University of California's Merced campus and more recently to Pittsburgh, PA. The movement of its offices corresponded to a shift in its focus toward domestic projects that sought to align its efforts as a loose network of autonomous primarily campus-based chapters operating at the intersections of engineering education and humanitarian engineering. ESW received formal non-profit status as a tax-exempt 501(c)(3)-type organization. ESW invites both engineers and non- engineers to become members and work on "wicked problems", complex problems that are experienced as local manifestations of global trends. Such wicked problems are contingent on multiple, interconnected factors manifest longitudinally at local, national and international levels (Gardner 2011). Global economic trends interrelated with local wages influence aggregate availability and consumption of resources including food, energy, water. Planning depends on local customs and, sociopolitical and legal institutions. Planet-scale environmental changes shape local climate and soil, affecting productivity and access to resources. In the interim, individuals and households experience the synchronic effects of food, water and energy insecurity as a daily struggle to survive.

ESW-organized Wicked Problems Sustainability Initiative introduces a broad problem to be addressed through service-learning projects implemented across classes that constitute a broad curriculum drawn across multiple campuses in North America. In addition, ESW offers online resources for students and professionals with an interest in sustainability issues to access content, training material, and interact with one another. In the following sections, two recent examples of students projects from the ESW website are analyzed and critiqued to demonstrate the need for ETH participants to be more reflexive in their engagement with development issues.

HOUSEThem: Homes Offering Unique Spaces of Engagement, Thriving Haitian Empowerment Movements

> *Excuse me, friends,*
> *I must catch my jet I'm off to join the Development Set;*
> *My bags are packed, and I've had all my shots,*
> *I have traveller's checks and pills for the trots!*

These opening lines from Ross Coggins' (1976) *Development Set* appear to anticipate

HOUSEThem, or Homes Offering Unique Spaces of Engagement, Thriving Haitian Empowerment Movements, an example listed by the Engineers for a Sustainable World (ESW) on their 2014 Wicked Problems in Sustainability Initiative (WPSI) web page. HOUSEThem is one of three *Social Entrepreneurship: Engineering for Humanity* projects carried out at the University of Pittsburgh where ESW offices are currently located. HOUSEThem's project document is carefully laid out in a manner that emulates the document genre typically produced at the higher end of the development value chain. Its Luz Sans font headings are tastefully highlighted in dark orange, and invite the reader to imagine sustainable lodging for international aid workers who "need a place to stay"[9] in Cap Haïtien, Haiti's second-most populous city. HOUSEThem is not merely a proposal to develop an equivalent of a travel hostel, budget motel (or, a two-star hotel, depending on the clientele) that overcomes the "unsuitability" and cost-prohibitive solutions for housing the average international aid worker who chooses to mark Haiti as a stopover. It is an ideological statement about the centrality of NGOs to Haitians' civic lives.

The entrepreneurial justification for the HOUSEThem proposal exudes blasé opportunism: "most hotels [in Cap Haïtien] are either expensive and excessively nice, or very inexpensive and unsanitary or unsafe"[1]. HOUSEThem's unique selling proposition is the creation of living spaces for transients that paradoxically function as symbols of sustainability. Earthquake resistant houses built out of recycled PET bottles will confirm the environmentally-conscious aid worker's aspirations to live a frugal, eco-sensitive for the few days they are in Haiti before returning to less sustainable dwellings they traditionally inhabit in the West.

HOUSEThem successfully manages to homogenize the site and the visitor and draw conceptual boundaries between stakeholders while framing its "affordable for international aid workers" guesthouses as spaces for community engagement where meetings with community leaders and local events can be organized. It is reasonable to assume that only a chosen few from the local populace will be able to regularly afford a lodge that sufficiently comports with the needs and sensibilities of the international aid professional. The project founders anticipate humanitarian workers and tourists as customers who might initially be targeted to pay ~USD 50/day for access to a 12-room guesthouse with indoor and outdoor plumbing, a communal kitchen and "multipurpose meeting spaces". The HOUSEThem document highlights the opportunity to attract non- Haitians, in particular the tourists visiting Haiti and invite them to interact with "groups focused on aid and development in Haiti". The HOUSEThem team hopes that interactions with other lodge members will help tourists better "understand the existing problems in Haiti" and find ways to contribute to Haiti's development.

HOUSEThem's team comprises undergraduate and graduate students in urban studies, industrial and chemical engineering are tech-savvy and look forward to advertising on review and travel websites such as Yelp and Tripadvisor. HOUSEThem's authors are however sensitive for the need to maintain a balance in the ratio of humanitarian workers to tourists. They express the hope that their guesthouse be filled "mostly with humanitarian workers" who will be attracted by affordable rates ($50/night in a city where the better hotels often run over $100/night) and the promise of staying in eco- friendly bottle guesthouses offering opportunities for socializing into the local NGO-led development community. HOUSEThem's vision for participation includes another group responding to the category of "them". Those for whom its facilities are not primarily intended are also invited to use the guesthouse's facilities when organizing meetings.

Members of the local community may make use of its "indoor and outdoor multipurpose meeting space" at a subsidized cost. Haitians' historical experience[10] with White visitors does not find a footnote in the HOUSEThem document. The HOUSEThem project description makes no reference to Haiti's status as the first independent nation in Latin America and the Caribbean, the second republic in the Western hemisphere and the only one to emerge successfully as an outcome of a slave rebellion, the only nation in the Western hemisphere to have repelled not one but three colonial powers. Haiti is instead reproduced in the student-produced text as a cliché – the "republic of NGOs"; the history of Haiti's relations with colonizing European nations is left unexamined in the students' rush to midwife its better future.

The HOUSEThem project document is not an isolated example of assumptions and inadequate considerations writ large into the emerging discourse of international service learning in engineering education. Aapka Ghar (Your home) is a company co-founded by four undergraduate chemical engineers at the University of Pittsburgh. Written toward ESW's 2014 theme of sustainable housing, Aapka Ghar exemplifies the incorporation of a homogenizing needs-focused perspective into the formulation of a problem statement by its author-founders. Focusing on Dharavi, the student authors of Aapka Ghar faithfully reproduce the stereotype of Dharavi being "Asia's largest slum", when it is in fact home over a million residents living and working out of a pastiche of neighborhoods organized along distinct linguistic, geographic, caste-based and religious affiliations. They do not find it necessary to reflect on Dharavi's status as a 135 year-old settlement of workers most of whom were originally and continue even today to be low caste, low status migrants. As early as the 18th century, Dharavi, then a rural community of *kolis* (fisherfolk) on the banks of the *Mithi* river had been deigned by British colonial government as a site for relocating polluting industries such as tanneries and kilns and migrant workers who came to "Bombay" in search of work from all over India.

Accordingly, the engineering student professional's engagement with the lives, experiences and choices/decision-making of Dharavi's 100,000 families can be "adequately" limited to punctuated, short-term problem-solving efforts that seek to help Dharavi's residents climb to the lowest rungs in Maslow's hierarchy.[11] This homogenizing focus on perceived physiological and safety needs of Dharavians illustrates what scholars[11] have described as the deficit approach of engineering to help (ETH). The general population of individuals, families and communities that constitute the category of users or beneficiaries of humanitarian engineering/social entrepreneurship projects are constructed primarily in polysemous, contradictory terms. Students largely perceive empirical reality from secondary sources and superficial immersions in "local culture" that average four to eight weeks at a time. As an initial step in the reproduction of the ideology of humanitarian engineering/service learning, a series of markers are argued to constitute certain "facts" about the "third world" (a term used by engineering educators as recently as 2008). Subsequently the third world denizen(s) appears to stand as an abbreviation or, shorthand for a disparate constellation of attributes identified by outsiders visiting from the developed world. This results from a series of markers that apparently speak of certain qualities that designate the other labels. Each label appears as a signifier summarizing, immediating and abbreviating those that are like it, together constituting - a cluster of characteristics that effectively describe the members of the community or population being "helped". For example:

a. *Poverty, illiteracy, lack of adequate infrastructure and safety are all signs of belonging to the*

third world/developing world.

b. *Individuals, communities and entire societies are labeled as third world or, belong to the developing world because they are poor, illiterate, and lack adequate infrastructure and safety.*
c. *Individuals, communities and entire societies are poor, illiterate and lack adequate infrastructure and safety because they belong to the third world/developing world.*

Thus, within the discursive space of ETH, the different labels applied to those being "helped" function separately as abbreviations and together as a chain of master-signifiers.[12] developing/third world are not only marginalized because they are poor, illiterate and lack adequate infrastructure and safety. Rather, their poverty/marginalization/lack of adequate infrastructure/safety stem from their (almost a priori) developing/marginalized/third world status. A number of attributes are linked to the Global South in the first statement via an apparently metacognitive, spontaneous, non-reflexive expression by the subject/actor. The second statement reads like an annotation obtained from collecting multiple and diverse responses regarding the necessary conditions for membership of the category third world/developing. Each response corresponds to an interpretive attempt to speak of the dispossessed in ways that are excluded by other attempts. Each interpretation is an attempt to be a master-signifier to other interpretations. Thus, lack of literacy and cleanliness, or abundant poverty, or, abysmal quality/levels of women's health, hygiene and safety, or malnutrition, or, poor infrastructure and corrupt governance are all aspects describing the state of developing or belonging to the third world. Leading finally to the third abbreviating of or naming this state of always being something other than/in addition to itself.

Local epistemologies of technology design and use are currently absent from scholarly conversations regarding engineering design for the developing world. The paucity of such alternative epistemologies of design in spite of the widespread prevalence of user- centered and human-centered approaches, informs my call for scholars to look beyond abbreviated signifiers and dimensions-of-difference toward identifying discourses of engineering design and ingenuity within grassroots communities. By learning how members of grassroots communities create and share knowledge during the design and development, researchers can transition from viewing community members as users who are dependent on researchers for technology solutions toward treating them as independent actors who are actively engaged in producing technology-based solutions for locally occurring problems. Furthermore, by studying how community members enact local ways of knowledge creation and sharing during technology design, scholars can identify convergences and divergences between local design practices and existing design principles and methodologies. Such points of convergence and divergence offer important points of entry for researchers interested in contemplating and transcending the circularity of relations describing the circumstances and activities of members of grassroots communities. The following section describes findings from my attempts to understand how knowledge is created and shared during engineering design and technology development *by* members of grassroots communities.

Design by Grassroots Communities

Grassroots communities typically consist of people who are distributed within a single, or in geographically proximate, local municipal units. Members of such communities share local geographical, material and social contexts of technology design and use. In studying grassroots communities as the active producers rather than passive receptacles for innovative technologies, I propose that scholars direct their attention toward communicative practices related to the creation and organization of knowledge within local communities. By innovative grassroots technologies I refer specifically to agricultural, mechanical or electrical technologies, which are designed by members of a local community to solve locally relevant problems in ways that represent significant improvements to the cost, quality, and performance of an existing technology. Grassroots community members' expertise as reflected in the success of their technology designs "resides in their intimate familiarity with and understanding of the particulars of the local situation". By success I mean the ability to produce a working solution to a locally defined and relevant problem in a particular geographical, environmental, social and material context.

The notion of contextual knowledge refers to the knowledge that arises from the everyday actions, practices and lived experiences of people who are thinking and operating within specific localized contexts and conditions.[12] Local knowledge has been described as developing out of experience with particular situations and comprising a strong tacit aspect to knowing. Elsewhere, scholars have described local knowledge as "the very mundane, yet expert understanding of and practical reasoning about local conditions derived from lived experience".[12] Due to its informal nature, local knowledge frequently struggles to achieve legitimacy outside local, community boundaries. The origins of local knowledge in context- and community-specific reasoning, practices and experiences means that such "everyday knowledge" can be distinguished from and is frequently discounted against "scholarly knowledge" which resides in the academy and is perceived to be grounded in science pursued by experts.

The difference between local and scholarly knowledge is not predicated on the presence of specialized knowledge, skills or expertise but rather in the kinds of knowledge and ways of knowledge construction that are deemed legitimate in different communities. The literature on ETH activities among grassroots communities emphasizes the design and use of technology for achieving social and economic development within such communities. Consequently, grassroots community members are conceptualized as socially and economically marginalized stakeholders whose primary relationship to the scholarly community is as potential users rather than as designers or developers of useful technology and technical knowledge.

Recognizing the generative potential of knowing requires engineering education researchers to conceptualize how differences originate in situated claims to knowledge. From a generative perspective, knowledge claims of grassroots community members are viewed as communicative practices associated with problem solving that are embedded in particular material and social contexts, rather than as exogenous variables influencing measures of efficacy in cognition and representation of information. Rejecting the conduit metaphor underlying the notion that ideas and knowledge can be treated and transferred as objects across individuals and groups, I present a practice-oriented perspective that does not seek to capture or translate knowledge, and instead asks researchers to study the ways in which practical knowledge is manifest through efforts to

draw attention to (or, away from) the particulars of a problem-solving situation.

Knowledge generation at the grassroots is the social process of manifesting the tacit aspects of grassroots knowledge and requires researchers, students and faculty to recognize local vocabularies of technology design and use. Viewing grassroots communities' communicative practices as situated in heterogeneous material and social contexts, allows students, faculty and researchers to reflect upon the performance of technology design and use in new ways by directing our attention to under-reflected upon aspects of grassroots communities' participation in such activities. To this end I ask the following research questions:

RQ1: How do grassroots community members talk about their design practices? RQ2: How does their talk translate into the "doing" of design?

Methods

This study is exploratory given that knowledge creation and sharing by local communities is a relatively under-researched phenomenon in the engineering education literature. The study warrants a naturalistic inquiry which gets as close as possible to the physical sites, activities, practices, and interactions of the individuals who are involved in generating and sharing knowledge during the design, development, and use of grassroots technological innovations. My primary research objective was to make sense of, or interpret the lived experiences, articulations and practices of agriculturists, artisans, craftsmen (and craftswomen), and other local makers and users of electrical and mechanical innovations at the grassroots. The Honey Bee Network - a key organizational stakeholder in the domain of traditional knowledge and grassroots innovation, mediated my access to such individuals and their communities.

Organizational Context: The Honey Bee Network

The Honey Bee Network (HBN), a quasi-governmental network operating across different parts of India and other countries in India, Africa, South-East Asia, and China, has been involved in the identification, documentation, incubation and dissemination of more than 100,000 locally developed ideas, innovations and knowledge practices (Gupta et al., 1999). As a global network of grassroots community members, agriculturists, scholars, policy makers, entrepreneurs and governmental and non-governmental organizations (NGOs) engaged in organizing indigenous grassroots community members and holders of traditional and indigenous knowledge, the HBN collaborates with a wide range of stakeholders in order to identify, document, validate, and disseminate instances of innovation and creativity at the grassroots level.

A fundamental imperative for the HBN is to communicate the authenticity and value of the contributions made by grassroots knowledge holders and grassroots community members, while ensuring their intellectual rights as primary authors, owners, and users of such knowledge and innovations. Consequently, a central epistemological issue for HBN stakeholders is to situate traditional knowledge and local innovations occurring at the grassroots within formal knowledge systems that are constituted by mainstream scientific, technological and entrepreneurial discourses. As argued earlier, local and scholarly communities may diverge significantly in terms of their epistemological assumptions and practices. Thus, studying the communicative practices among the diverse epistemic communities, which participate in the design and development of

grassroots technologies, presents an important point of entry for studying knowledge sharing between the developers and users of technology. Similar to other fieldwork that has a transnational orientation, I describe a multi-sited research design, which addresses the distribution of grassroots technologies across different geographical locations, sociocultural contexts, and application areas.

Research Design

Observational and interview data were collected in two phases by the author, who is of Indian nationality and is fluent in Hindi, a language spoken and understood across all of the sites of data collection. Data collection in the field consisted of daily observations of grassroots community members' routine activities. These observations were conducted primarily as "go- along" interviews with key informants including grassroots community members, their collaborators, family, friends, and innovation users about their experiences, routines, and practices related to innovation at the grassroots. Go-alongs were supplemented by semi- structured interviews where I queried grassroots community members regarding their motivations for and experiences during the design and development of particular innovations. I also conducted archival research on documents pertaining to the design, development and use of grassroots technological innovations (e.g. summary reports on grassroots community members and their innovations, reports on the results of laboratory tests on the material properties of innovations, market research and prior art searches on innovations, correspondence between grassroots organizations, design collaborators and entrepreneurs interested in technology transfer).

Gaining Access

Following an early set of informal interviews with the administrative members of the HBN to establish access to the documents and identify key grassroots community members and their communities, I participated in a 140 kilometer, five-day Shodh Yatra on foot across 19 rural communities in India with members of the HBN seeking to identify grassroots knowledge grassroots community members (GKI). The Shodh Yatra is a program organized by SRISTI (Society for Research and Initiatives for Sustainable Technologies and Institutions - a non-governmental, non-profit organization participating within the Honey Bee Network) for scouting, sharing, and disseminating knowledge of innovations at the grassroots level. Participants in Shodh Yatras include adult volunteers who walk through rural and semi-urban communities across different parts of India and interact with community members at public events that are organized with the objective of sharing grassroots knowledge and celebrating the efforts of community members who address local issues in innovative ways.

During the four-day walk from Silli to Hundru in Jharkhand state, I traversed eighteen villages as a volunteer and participant observer with other volunteers and members of the HBN. A snowball approach was initially employed for recruiting informants during the Shodh Yatra, building off known informants in the form of community representatives, grassroots community members within the community, and HBN volunteers. Each initial interviewee was requested to recommend and introduce other participants associated with the development or use of community-specific technological innovations. Recruitment through snowball sampling rather than random sampling also likely increased the comfort level of participants who may have felt

more inclined to participate in research when approached through known informants rather than strangers. As part of the initial portion of participation with the HBN community, the Shodh Yatra was an opportunity to dissipate the uneasiness that potential informants might feel regarding my status as a researcher. In fact, interactions during the Shodh Yatra with Amrutbhai Agravat, one of the earliest grassroots community members associated with the HBN, helped organize the second phase of data collection. By the end of the Shodh Yatra I had become familiar with the organization of the HBN and was able to identify specific representatives who subsequently helped him to gain access to innovator communities. These representatives included two HBN scouts, two senior researchers who worked in the documentation department of the NIF, and a representative of SRISTI – the primary NGO responsible for scouting and documenting grassroots innovation in the HBN.

During the Shodh Yatra, I experienced a sense of isolation from the individuals whenever he sat down to write notes in front of them. Emerson, Frets, and Shaw (1995) discuss this perception of awkwardness in terms of ethnographic marginality or the inability of researchers to participate in goings-on in a "natural" manner when they make overt attempts to impose the "exogenous project of studying or understanding the lives of others-as opposed to the indigenous project of simply living a life in one way or another" (p. 36).[13] They argue that jotting in public reaffirms the outsider status of the ethnographer by demonstrating that their purposes for participation in events are different than those of others. To reconcile with this sense of alienation from the setting, overt note taking was limited to situations where I was alone, or during formal interviews. Interestingly, informants frequently mentioned that the presence of the recording equipment was indicative to them of the seriousness of the work being done, and encouraged me to use such equipment often.

Data collection lasted anywhere between six to ten hours per day with approximately four to six hours captured on video and through note-taking, and the remainder through a combination of audio recording and note taking. Informants were most amenable to a sit- down conversation in the hours after dinner. Participant observation was typically organized around three events which occurred daily and across all phases of data collection – recording and taking notes upon arising and completing morning ablutions, video and audio recording when interacting with participants until lunch time, after which most informants took a siesta. Video recordings were tagged with brief single sentence descriptions of the date, time, actors, and events occurring in each recorded video clip. During the afternoon, note taking was resumed, and were written in the third person to the extent possible in order convey observations of what people were doing and saying, and to maintain multiple voices in the narrative. Local idioms and phrases were preserved and transliterated into English. Video and audio recording of interactions began again after the siesta and continued intermittently along with unrecorded observations and conversations until dinnertime in the late evening. Breaks were not planned and relied largely on battery life and an assessment of the need to record ongoing activity.

Embedding within the Community

Following the Shodh Yatra, I conducted eight six-day site studies to observe and record the everyday practices of eight grassroots community members and their participation within local communities and the HBN. Consistent with a reflexive methodological approach, at the ethnographic sites I employed go-along methods of data collection to facilitate immersion in the research site while enabling data collection across a broader range of informants. A go-along emphasizes the dynamic aspects of informants' lives and tries to obtain their interpretations in situ, that is, in circumstances where such interpretations might emerge through conversations carried out while engaging in daily practices and routines. The go-along method provides a "systematic and outcome- oriented" procedure for ethnographers to "hang out" with multiple informants in different social situations.[13] Given that key informants for our study included grassroots community members, collaborators, as well as users, there was a need to establish breadth during data collection by spending comparable amounts of time with each informant. Furthermore, there was a need to collect observational data in a manner that allowed us to access informants' experiences and interpretations simultaneously. For example, answering questions about how an innovation becomes useful in a particular context requires observing the use of the innovation, focusing on how the informant interacts with the innovation, and seeking to capture the perceptions and interpretations of informants regarding their use of the innovation.

The "go-along" approach enabled us to capture a "stream of perceptions, emotions, and interpretations" in relation to interactions with the innovation in a variety of circumstances.[13] Furthermore, the go-along method provided an opportunity to shadow informants as they engaged in daily activities in familiar environments. While these activities were contrived in that informants dealt with an intrusion upon their lived experiences, because the go-alongs were frequently conducted with informants when they set out to meet friends or family, they provided an opportunity to uncover "aspects of individual lived experience that frequently remain hidden during participant observations, sit- down interviews and more experimental types of go-alongs".[13]

A useful outcome of this approach was the improved access gained to the communities in which the researcher was embedded. During go-alongs the researcher was introduced to collaborators, friends, and peers in the local community, providing the opportunity to interview a second layer of participants about their perceptions regarding the innovator's pursuits, and its influence on them or the community. Thus, the go-along approach provided a means of developing field access and validating researcher interpretations against the perspectives of multiple informants. The approach also facilitated a rapid rate of immersion in the research site to enable the collection of rich data in a short period of time.

In sum, this approach provided a powerful methodological tool to gain access to a community, and interpret their practical knowledge as a function of their "relevances" or the composite of personal interests, skills, dispositions, and sensibilities. The go-along method also provided insight into the spatial practices of grassroots community members, that is, how they engaged with objects and others within their physical and social environment, and how these practices became meaningful in shaping the grassroots community members as members of their local community. In doing so, I was able to explore grassroots community members as grassroots

community members in-context, both embedded in and respondent to the specific geographical, material, and social contexts. At the same time this method provided a lens into the communities themselves as active producers of innovative technologies, and the organizing and communicative practices that constituted the production and knowledge.

Navigating the environments of the informants also helped me to construct their lives and their innovations through their everyday interactions – the sights and sounds that constituted their experience would otherwise not be relatable through observation or interviewing. Furthermore, as informants reflected on their connection to places and people in their local environment I was able to map the larger social network of each informant in real time and real space. As informants moved around in their local environment and mentioned incidents or events involving people who lived in the vicinity or were passed on the road, rich details were recorded that provided the opportunity to construct the social architecture of the informants' local settings. This approach reflected and recorded the innovations as evolving representations of the practices among grassroots community members and their collaborators.

Finally interpretive sessions in which I debriefed on my field experiences with HBN representatives, helped generate analytic insights that guided the organization of collected data in addition to informing the impetus for future data collection. During one such session, I discussed my difficulty in getting grassroots community members to describe the development of a technology's design using drawings or sketches. My conversations with HBN representatives led me to interpret this lack of representation among grassroots community members as possibly indicative of the discursive nature of collaboration during the design process. This interpretation was supported by my observations regarding the frequent visits by grassroots community members to workshops where prototypes were being fabricated. Subsequent data collections focused on "go-alongs" in which I would accompany the innovator to workshops and spend time observing the conversations between grassroots community members and the workshop owners and workers. Thus, interpretive sessions helped identify sites where communicative practices associated with the design, development and use of grassroots technologies were being enacted.

Integrating Research Findings into Teaching

During analysis, the practice of fariyad emerged as a reflexive practice of seeking and receiving feedback from users on the functionality of the technology artifact suggests that the apparent incompleteness of technology artifacts is emphasized and reiterated by grassroots community members who understand the need to adapt the artifact to user needs. Fariyad thus represents the communicative enactment of both instrumental and empathic motivations for design-based innovation at the grassroots. As an instrumental practice, grassroots community members rely on fariyad from users regarding the usability and functionality of their designs. They also rely on fariyad when requesting support from organizational collaborators for the improvement of their designs. Support may take the form of requests for testing performance claims made by the innovator, requests for funding in the forms of grants and subsidies, value- addition requests such as those pertaining to aesthetics and functional improvements such as durability, cost, efficiency, and knowledge protection through patent applications. As an empathic practice, fariyad may be enacted through self-determined reflexivity. Amrutbhai's concern for the health of farm animals and laborers, and Bachubhai's observation of the needs of fellow farmers demonstrate the

potential of reflexivity in motivating design that addresses the unarticulated as well as the articulated problems of users. By enacting fariyad, grassroots community members in empathy toward their social and material environment participate in a reflexive situating of their self.

Fariyad also functions as the self-determined enactment of other's contexts into one's own. For example, Amruthbhai Agrawat is an artisan who develops innovative agricultural implements for improving the productivity of farmers who employ cattle- driven ploughs while working on the farm. He recalls observing draft animals while in the field:

I routinely observed that the cattle working in the field were covered with bruises and calluses on their neck and shoulders. I saw that the animal was performing two functions – it was pulling the cart and simultaneously supporting the weight of the cart. It had to support the weight of the cart because most carts had only two wheels at the back leaving the front end to which the animal was yoked unsupported. Also, the animal was harnessed to the cart in a way that made it difficult to make sudden or sharp turns with the cart on the road or in the field. The harness was stiff and could not be rotated to accommodate the turns. The design of the carts and harness was not only injuring the animals but also reducing their stamina and efficiency. I had to do something to ease the burden on the animals.

Amrutbhai also observed the considerable strain of farmers and female laborers in transporting and loading the carts in the field. Amrutbhai recalls sharing these observations with local farmers when they visited his workshop to repair or purchase farming implements:

> The farmers agreed that the cattle were placed under tremendous strain. I wanted to come up with a solution that could address the problems faced by both the animals and the humans who were toiling in the field. Through my conversations with the farmers I came up with the idea of adding four wheels to the cart in order to leave it self- supported. A rotating harness could allow the bullocks to turn with less strain. I also thought of using a hydraulic system for lifting the cart in a measured/gradated fashion. I had seen such a system on tractors. I decided to develop a design for the carts that would alleviate the suffering of both animals and humans.

Amrutbhai's concern for problems faced by both animals and humans working in the fields reflects a degree of sensitivity toward the experiences of the users of his designs that goes beyond instrumental contemplation.[14] His motivation to understand and help is indicative of an empathic approach to not only the design of farming implements but also the lived experiences and contexts in which the needs of others can be perceived.

Such willingness to "identify oneself with the feelings and ideas of another person"[14] is also exhibited by Bachubhai Thesia, a farmer from Kalavad in the Jamnagar district of Gujarat. Bachubhai designed a lever-operated tractor that would allow farmers to ride a tractor in much the same way as they would ride a plough pulled by cattle. Just as the animal turns when the rope tied to them is pulled to the left or right, the lever-operated tractor turns left when the left lever is pulled or the right lever is pushed. The tractor also imitates cattle in the way it stops when either lever is pulled hard. Bachubhai's design for the levers incorporates the functions performed by the steering, clutch and braking systems in conventional tractors. When asked about his motivations to design a lever-operated tractor, Bachubhai says:

> I designed the lever-driven tractor for use by farmers who were more comfortable with using one hand at a time to direct the bullocks in the field. These farmers were unfamiliar with using the steering wheel and gear systems on tractors. Many of the farmers I met at the mathuli (the town square where people congregate after dinner to chat) were considering shifting to tractors because of the high cost of maintaining cattle. However, most tractors that were available in the market were priced out of their reach. These tractors were big, heavy vehicles that consumed a lot of diesel.

Bachubhai designed the front wheels to run at an angle close to 90 degrees allowing the tractor to achieve nearly 360 degrees of rotation on its central vertical axis. This feature allows farmers to turn easily when working on small plots of land. Designed to be lighter and more maneuverable than conventional tractors, Bachubhai's design utilizes a smaller capacity diesel engine that consumes less fuel. As Bachubhai explains:

> The weight of the tractors would compact the soil making it difficult for the roots of sown crops to penetrate the soil. The compacted soil also makes it difficult for water to trickle down and its runs off [erodes] the topsoil. Bigger tractors are also difficult to work with on the small plots of land owned by most farmers. The smaller size of the lever-operated

> tractor allows for sharper turns and does not compress the soil as a heavier tractor would. The levers allow one hand to be free at all times.

I have woven findings from the research described above into class projects where two sections of 23 and 22 students respectively worked on identifying technologies for social justice and strategies for their improvement and dissemination. Here I report on my interactions with three third year and senior students of mechanical engineering who had previously participated in a semester-long design project to develop microeconomic kits comprising technologies that were intended to support economic activity in developing regions. A discussion about the practice of fariyad helped students to problematize their assessment of the economic and technology needs of low-income urban neighborhoods in Peru. The students were evaluating a pedal-powered washing machine that they had designed in the previous semester. Their task was to construct a decision matrix comprising possible improvements to the functional and aesthetic aspects of the pedal-powered washing machine listed in order of significance. Initially, the students were focused on improving functional aspects such as the spin cycle efficiency, increasing load size, preventing mechanical failure and making the mechanism easy to repair. During a student conference the students reported on the strategy of understanding the "Voice of the Customer" as a possible technique for refining the priority list. Drawing on the research project, I described to the students how the practice of *fariyad* refers to feedback obtained from users (e.g., customers, collaborators), and typically specifies a particular problem with the technology. The word fariyad loosely translates as an appeal, or plea, made to someone. In the context of grassroots grassroots community members, fariyad refers to the requests and criticisms offered by grassroots community members as well as users when communicating in regard to changes in the features or functionalities of an existing technology. The collocation of the innovator and users in the local community affords opportunities for such interaction.

Following the student conference, the students spent ten days revising their decision matrix and returned with the following list of priorities: First, they noted that their cost estimates were too high with each machine approximately equivalent to average monthly wages in Peru. Second, they argued that all potential users might not also be potential consumers. Women who typically perform cleaning activities might not possess the same purchasing power and those who had purchasing ability might prioritize other more immediate needs. Third, they acknowledged their assumption that poor households in Peru would prefer a pedal-powered alternative to its electricity-driven counterpart was quite likely a patronizing and unrealistic one. Poorer households were just as likely to prefer energy-intensive solutions except that they lacked regular access to electricity.

Conclusion

While the number of engineering-to-help (ETH) activities has increased along with an expansion in the geographic scope of associated operations, there has not been a critical examination of the assumptions and biases of faculty, students and facilitators who participate in ETH activities. In the present study, I analyzed two exemplar projects made available by the organization Engineers for a Sustainable World and identified key assumptions and biases regarding the conditions of and differences between communities in the Global South and educators, researchers and students located in the university campuses and educational organizations of the

Global North. Drawing on ethnographic research on grassroots technological creativity by textually less-literate members of grassroots communities, I derive themes that have served as points of discussion with student teams working on extending semester-long sustainability projects.

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