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Logics of Collaboration: An Ethnography of Codesign in the Brazilian Amazon

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Abstract

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Engineers working internationally are increasingly concerned with the social impacts of their work. New frontiers in design show promise in helping practitioners address these concerns. One of these is codesign, a practice of making stakeholders co-decision-makers in the design process. Codesign has the potential to greatly improve the social sustainability of engineered products, but some concerns remain surrounding codesign's practicability in engineering. I explore three such concerns: that conflicting institutional logics may undermine codesign's collaborative aspirations, that codesign can perpetuate developmental idealism, and that codesign may insufficiently account for the needs and perspectives of marginalized populations. Through more than a year of ethnographic research, including dozens of interviews and hundreds of hours of observation, I examine the realities of codesign as it is carried out by a team of engineers in the Brazilian Amazon. I find that conflicting logics do undermine codesign at times, but that the engineers are still able to explore new tools and practices for socially sustainable engineering, even in times of codesign failure. I also find that the engineers are better equipped to respond to modernizing stakeholders than they are traditional ones. This may lead to the spread of developmental idealism and the further marginalization of disadvantaged groups.

Keywords: codesign, institutional logics, development, engineering

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INTRODUCTION

Professionals in fields like design, consulting, and engineering know how difficult it can be to bridge the gap between one's own training and the expertise of a client who has spent day after day in the context of a problem. Clients hold valuable clues for professionals that can reveal new paths forward and help make solutions stick. The challenge for professionals is often interpreting and incorporating those lived experiences into the solutions they provide.

In engineering for global development (EGD), engineers bring mechanical expertise to the design setting but, according to those interviewed for this study, it is normative to toss designed solutions "over the wall" where they may or may not have the intended impact. Products sometimes clash with local customs, prove to be short-lived, or have unintended negative consequences. Increasingly, engineers and other experts sense the need to bridge the gap between their own expertise and that of their clients (Sanders and Stappers 2008).

One way that EGD practitioners attempt to create more socially sustainable products is by including social impacts in their models, but doing so is far from straightforward. Social impacts have joined economic and environmental impacts to make up the "Triple Bottom Line" (3BL) approach (Melles, de Vere, and Misic 2011; Rainock et al. 2018). Indeed, because of its cross-cultural focus, global development work provides many clear examples of why accounting for social impacts is so important. Engineers working in developing contexts find that all the mechanical expertise in the world cannot compensate for cultural and contextual unfamiliarity (Witmer 2018). However, social impacts are difficult alone to identify, let alone to measure and manipulate. Economic and environmental impacts are much more easily modeled and predicted than are social ones, and while some would attribute this to human irrationality, some engineers believe that the proper tools and techniques have simply not yet been developed.

A better accounting of social factors requires greater awareness of local context, and some engineers have begun collaborating with local stakeholders in the design process to get this richer perspective. Direct engagement of users in decision-making may shed light on complex social impact concerns and may help curb the shortcomings of traditional development work, but such collaborations bring their own challenges. Collaborators can come from a multitude of distinct backgrounds which shape the way they approach and define the project. Additionally, cultural, geographical, and technological obstacles may hinder communication. Especially when done from a distance, interaction may not even be possible on the level necessary for productive collaboration, and if the collaborative effort becomes merely symbolic, it may mask the colonial tendencies of traditional development.

Through ethnographic research spanning more than a year, I explore what happens when a particular team of engineers attempts a process they call "codesign," a practice of engaging local stakeholders as co-decision-makers to develop a mechanized *mandioca* (cassava root) peeler for rural farmers in the Brazilian Amazon. Specifically, I ask: What challenges do these engineers face when enacting codesign internationally? Through the lens of institutional logics, I look at how different stakeholders embody distinct logics, how these come into conflict with one another, and how the engineers navigate the conflict. Then, I connect these findings to issues of development and marginalization.

I argue that competing logics undermine the collaborative aspirations of codesign in this project. The logic of engineering was, at times, incompatible with the ideals of codesign. However, the engineers in this study were motivated by a broader objective: Stretching the engineering logic toward greater awareness of social factors. By this I mean that, when tension emerged as a result of these engineers' dual commitments to engineering and to codesign, it provided fertile ground for exploring new tools and expanding the scope of the engineering logic. This act of leveraging resources to positively transform an institutional environment (what some organizational scholars call *institutional entrepreneurship*) was, paradoxically, achieved even in areas of codesign failure (Maguire, Hardy and Lawrence 2004; DiMaggio 1988). I document how that happened. In short: When tensions arise between competing logics, the engineers questioned the assumptions of traditional engineering and pursued new tools and practices. A focus on positively transforming the institution of engineering may, however, distract our attention from the real impacts of codesign's success or failure. To shed further light on these concerns, and hopefully provide guidance for future practitioners, I discuss some of the possible consequences of this codesign effort through lenses of developmental idealism theory (A. Thornton, Dorius, and Swindle 2015) and marginalized populations.

The argument proceeds in the following way: First, I describe codesign and some of its potential challenges, drawing heavily from neoinstitutional theory, developmental idealism, and the study of marginalized populations. Second, I discuss the research context and qualitative methods used. Third, in the results section, I provide an ethnographic depiction of codesign and some of its challenges. Fourth, the discussion section, I examine the evidence more analytically and connect it to relevant literature. Finally, I end with a short description of limitations and conclusions.

BACKGROUND

Codesign and Engineering for Global Development

New frontiers in design blur the distinction between users and designers. Human-centered design, design sprints, and design thinking are just a few recent trends that suggest a more fluid and collaborative future for design (Sanders and Stappers 2008). Codesign, or co-design, takes collaboration even further. An academic journal bearing the name CoDesign, established in 2005, has facilitated the exchange of case studies and best practices, but much of codesign has yet to be studied empirically. Put simply, codesign calls for traditional boundaries between designer and user to be made purposefully porous (Andersen, et al. 2015). With a number of stakeholders (future users, local gatekeepers and others invested in a successful outcome) typically included in design decisions, some have described codesign as a process of joint discovery between designers and users wherein the former is better able to grasp the local experience and the latter is better able to envisage new possibilities (Simonsen and Robertson 2013). For engineers in particular, codesign presents an alternative to traditional, “over-the-wall” design. By engaging local stakeholders directly in design decisions and in the creation of the "system" in which the final product would ultimately be embedded, engineered products might be better suited to their social environments.

Codesign is best understood in the context of its parentage. The practice descends from the participatory design movement of 1970s Scandinavia which sought to democratize the design of the workplace (Sanders and Stappers 2008). As with participatory design, codesign is frequently portrayed as a “mindset” more than a specific set of tools or practices (Simonsen and Robertson 2013). Furthermore, some argue that the strength of such methods is their ambiguity, their opposition to rationalist views of human activity (Simonsen and Robertson 2013:4). In the eyes of its proponents, codesign, like participatory design, may be distorted if used as a set of prescribed design procedures.

For designers, the nebulous nature of codesign enhances creativity and broadens possibilities (Sanders and Stappers 2008); for engineers, codesign is an intriguing prospect but a potentially fraught one. Engineers, like designers, rely on creativity to design products, but they tend to have more specialized expertise and therefore may struggle to collaborate with non-technical stakeholders. Where aesthetic factors are often a matter of preference, mechanical factors are a matter of functionality, which presents an interesting challenge for engineers who seek to incorporate codesign into their design work. As the engineers in this study explain, "the idea was never for locals to tell us what screws to use." The need for something like codesign in engineering may be apparent, but its application is less clear.

For engineers working cross-culturally, codesign could have major benefits. Products that are developed outside of a local context and with limited understanding of a culture can lead to a variety of negative consequences. Scholars have documented the need for technologies to account for culture (C. Lee 2003). Engineered products that fail to do so may go unused for reasons as simple as being the wrong color or requiring electricity where it is unavailable. They may also, however, have more serious effects, as noted by globalization scholars, like undermining local economies, increasing inequality, or trampling local customs (Goldsmith 2002; Hassi and Storti 2012). Each of these concerns could be potentially alleviated by successful codesign. Given its democratic ethic, the threat of colonialism, overt or implicit, might be best addressed by locals "owning" more of the solution (Melles, de Vere, and Misic 2011). Empowering locals to co-discover new solutions may produce more long-lasting and equitable development.

Codesign may also reveal new opportunities for progress on local terms. Cross-cultural work is increasingly scrutinized for its colonial tendencies—and rightly so. Less obvious, however, is the well-intentioned but potentially patronizing view that traditional cultures ought to be kept pristine at all costs. An overly "romantic" view of the exotic, the foreign, and the traditional can have its own detrimental effects on populations seeking change (Cowen 2009).

Empowering locals through collaborative design may shed light on areas where wealthy nations have exercised excessive caution toward developing societies, even treating them at times as quaint curiosities (Guillen 2001; Foster 1982). Perhaps codesign can illuminate a path away from our colonial and "romantic" tendencies alike, toward a form of global development engineering that more fully treats its local counterparts as agents.

Three Challenges to Codesign

Little has been written regarding the sociological implications of codesign in international work. However, sociological literature sheds light on three potential areas of concern to codesign. I treat them as sensitizing concepts that alert us to codesign's potential pitfalls. Greater awareness of social theory may help designers understand and even anticipate complications when attempting codesign, but it also may highlight innovative ways that codesigners navigate the collaborative process.

First, the institutional logics perspective (P. Thornton, Ocasio, and Lounsbury 2012) sheds light on the way institutions shape the priorities, preferences, and perspectives of individuals, and how individuals in turn shape their institutional surroundings. This is relevant to codesign because it helps us understand the diverse rationalities at work in a collaborative project. For example, the logic of one individual may seem entirely irrational to another, and definitions of success may vary greatly from one collaborator to the next. By examining codesign through the lens of institutional logics, we can better understand the complications and opportunities presented by such collaborations.

Second, developmental idealism (A. Thornton, Dorius, and Swindle 2015) provides a critical framework for discussing the problematic assumptions of "development" work, and even calling into question the term itself. This literature outlines how western forces have reshaped the world in their image. By connecting developmental idealism to codesign we can discuss some of the subtle ways in which codesign may address some of developmental idealism's concerns and how it may risk perpetuating others.

Third, a discussion of marginalized populations (Peet and Hartwick 2015) can help us better understand the needs of those most likely to be left behind by globalization's relentless thrust. Codesign engages stakeholders in the design process, potentially making it more democratic. Less clear, however, is how this ideal can be achieved by engineers working in a foreign context, or which stakeholders' voices should be most central. This discussion will examine how codesign accounts for marginalized populations and how they might be better served.

I address each of these challenges in turn: First, I provide a concise review of institutional logics literature, including neoinstitutional theory (DiMaggio and Powell 1983; Scott 2014;), the institutional logics perspective (P. Thornton, Ocasio, and Lounsbury 2012), and institutional "myths" (Meyer and Rowan 1977), and I connect these to codesign practices. Second, I connect codesign to the concerns of development scholars, relying primarily on developmental idealism theory (A. Thornton, Dorius, and Swindle 2015). Third, I present a brief description of marginalization literature relevant to codesign.

Conflicting institutional logics. One possible way of thinking about codesign is through the lens of institutional logics, and past scholarship helps direct our attention to how competing logics might undermine codesign efforts. The body of research known as "neoinstitutional theory" was pioneered by organizational theorists interested in how institutions shape and constrain the organizations, and therefore the people, embedded within them (Meyer and Rowan 1977; DiMaggio and Powell 1983). For example, the institution of engineering as a profession has certain values, assumptions, and perspectives that filter down to engineering firms and their employees. This shared understanding is an example of what Meyer and Rowan called the "myth" of an institution.

This literature sheds light on two important implications. First, some institutional forces are so subtle, so taken-for-granted, or so all-encompassing that they shape the very lens through which individuals see the world. In recent years, organizational theorists have come to refer to these lenses as institutional logics (P. Thornton, Ocasio, and Lounsbury 2012). Logics can often be identified most easily in points of conflict between different groups. One might imagine, for example, a record label executive (economic logic) clashing with the artistic values of a signed musician (artistic logic). What's more, multiple logics can come into conflict within the same organization and even the same individual, such as when an organization attempts to operate with both an economic logic, as a profitable business, and a social logic, as a charitable organization. In such hybrid organizations, it is as if such an organization is playing multiple games at once and is "partially at war with itself" (Kraatz and Block 2008). The effect of conflicting logics within a single organization or project has been documented in a number of sociological studies (Espeland 1998; Kraatz and Block 2008; Besharov and Smith 2014; Heimer 1999). Espeland notes that values held tightly by one group may seem utterly irrational to another, which can lead to conflicting objectives. Such tensions can undermine the success of an organization, but they can also produce novel solutions to complex problems (for example, Smith and Besharov 2019) and push the boundaries of existing logics (Jay 2013).

Second, actors within an institution are prodded toward compliance with the “myths” of their institution. For an engineer or organization of engineers to be seen as legitimate, they must at least appear to comply with the engineering mythos (such as a focus on measurable impacts, funding from NSF, publications and patents, etc.). Some actors within an institutional landscape carry greater influence than others (Friedland and Alford 1991). If top engineering firms begin to focus their efforts on sub-Saharan Africa, even firms with little practical interest in sub-Saharan Africa may turn their attention to the region, in part because doing so increases their apparent legitimacy as an engineering firm. When elements of an institutional myth conflict with the actual interests or needs of an organization, the organization may incorporate those elements only ceremonially, allowing it to decouple its compliance from day-to-day functions (DiMaggio and Powell 1983). Returning to the sub-Saharan example, an engineering firm that works predominantly in South America may create a small team dedicated to sub-Saharan Africa merely to comply *ceremonially* with the new standards of legitimacy. In many cases, such teams go underfunded and unsupported because their existence is primarily symbolic (Meyer and Rowan 1977). Organizations tend to have elements of both actual and ceremonial compliance toward the institutional forces around them, and it is not always clear where the one ends and the other begins.

In the context of codesign, this literature directs our attention toward two potential problems: First, the literature suggests that the engineers' collaborative efforts may be undermined by conflicting logics. Codesign brings together designers (or engineers) and users to share in decision-making responsibilities. A project may involve more than one group of future users, each with different values, assumptions, and priorities. While accounting for "multiple voices of future users" was one of the founding principles of participatory design (Simonsen and Robertson 2013), doing so can be extremely difficult in practice. Disparate groups enter the design setting with differing assumptions, values, and perspectives, which shape how they define and measure success. Engineers attempting codesign are faced with the extraordinary task of incorporating and responding to vastly different stakeholder logics that may be at odds with the engineering logic and with each other.

Second, the literature suggests that certain aspects of codesign may take place only ceremonially to show compliance with a "codesign logic" in which collaborators are temporarily embedded. Codesign can be fruitfully viewed as its own logic—one that values collaboration, fluidity of roles, and participation. It represents a type of no-man's land where opposing logics might negotiate terms. Just as organizations might decouple ceremonial compliance from their day-to-day activities, the various parties involved in a codesign collaboration may find themselves ceremonially engaging in codesign while more effectually operating within another logic. For example, a local stakeholder may go through the motions of providing user feedback while in actuality he defers to the expertise of the engineers. Or for an engineer, if functionality is the highest priority and the project is seen as essentially mechanical in nature, she is likely to revert to what most resembles progress in that logic, such as energy efficiency or technical sophistication. In such a case, it is possible for codesign activities that move focus away from mechanical factors to become mere hoops to jump through. In other words, where tensions arise between codesign and other logics, the tools of co-design, such as collaboration, role fluidity, ethnography, interviews, and frequent engagement may become largely symbolic.

Developmental idealism. Another way of thinking about codesign—and the challenges it may face—is through the lens of globalization. Engineers and designers interested in wrestling with complex problems around the world are often met with skepticism from scholars, activists, and others, and not without reason. Many well-intentioned development projects of recent years have resulted in unforeseen negative impacts. Development projects with dubious motives have abused traditional cultures and undermined local economies (Goldsmith 2002). Even projects with the best of intentions, however, frequently lead to unintended negative consequences (Guillén 2001). For example, Nieusma and Riley (2010) examine the problematic assumptions and tendencies often embedded in 'engineering for development' programs through a case study method not unlike this one. Their study identifies several mechanisms through which development projects produce unintended negative consequences, including, for example, engineers implementing cultural ideals of their own that may not fit the local context.

While some negative consequences are immediate and easily identified, others are more subtle and prolonged. In a 2001 article and a later book, Arland Thornton (2001; 2005) began developing a theory of 'developmental idealism' that seeks to shed light on the promulgation of Western cultural ideals. He defines developmental idealism as "a widespread and powerful cultural model constituted of a set of beliefs and values about development, including its causes and consequences" (A. Thornton, Dorius, and Swindle 2015). The theory proposes that this cultural model emerged among elites of Northwest Europe, ultimately providing the curriculum for development projects in countries that are perceived to be "lagging" behind Western exemplars. Indeed, the global development enterprise commonly assumes that development follows a linear trajectory marked by advancements in, for example, mass education, individualism, economic growth, democracy, and capitalism (A. Thornton 2014; Heaton and Cammack 2011; A. Thornton 2001). These “development indicators” are seen as the natural endpoint of all societies.

One aspect of codesign highlights the relevance of developmental idealism to this study. In codesign, the ability to share in decision-making responsibility requires that common ground be established between collaborators of different backgrounds. To draw on the terminology of the previous section, individuals from competing logics seek areas of shared meaning where common definitions of success can be established. In principle, codesign incorporates a wide variety of stakeholder voices, but in practice some voices are more compatible with designers and engineers than others. The ability to speak English, familiarity with modern technology, access to high-speed internet, and interest in development are just some of the traits that might make one potential collaborator a more likely candidate than another. The appearance of a "rational" temperament may be enough for engineers to rely on some individuals and deprioritize others.

In the case at hand, codesign may give the appearance of cultural responsiveness while in actuality promoting the colonization of a particular cultural model that, rightly or wrongly, is assumed to be superior. Even the radically democratic ideals of codesign may lead codesigners to impose their own assumptions about who ought to have a seat at the table. For example, if engineers seek to hand over greater control of the design process to locals, they may find themselves either relying on existing power structures, which could aggravate inequality, or else imposing their own models of equality as a prerequisite for collaboration.

It is possible that partnering with the most accessible and reliable figures in the target community gives a false sense of cultural sensitivity, when in fact key stakeholders represent only the most Westernized of possible constituents. Informants with English-speaking ability and a modernization mindset can be valuable bridge-builders between the engineering team and locals, but can also bias design research toward a modern, Western mentality. Engineers accustomed to relying on objectivity and measurability may find no objective answer to the difficult questions raised by developmental idealism. If this expectation bears out, we may see differences between stakeholder perspectives around developmental idealism themes, and that the engineers rely most heavily on the voices that reflect modern, Western, rational ideals.

Marginalization. A third challenge for effective codesign is the potential further marginalization of disadvantaged groups. As established above, codesign may give the appearance of cultural sensitivity while in reality favoring the stakeholders that are most relatable to designers and engineers. It may not be clear, in practice, who ought to collaborate in collaborative design. If this is true, disparities along lines of race, class, and gender may be magnified through the codesign process. Traditional engineering, for example, focuses its attention on a single client or group of clients, and typically responds to the preferences of whomever is funding the project. In codesign, where multiple stakeholder groups are included and the role of "client" is intentionally obscured, it is unclear whose values will take priority. Codesign purports to respond to the needs of locals but might not fully recognize that what is best for some locals may be detrimental to others.

One way that codesign may fail to account for the needs of marginalized groups is by relying on quantitative data that fails to account for the traditional values. Sociologists have noted an increased demand in recent decades for quantitative measures of social phenomena (Espeland and Stevens 2008). Engineers are uniquely qualified to solve some of the world's most difficult problems, but progress is commonly defined using measurable outputs and quantitative indicators. This raises questions regarding the type of data that such work can incorporate. As Espeland points out (1998), engineers working on the Orme Dam were much more able to incorporate economic and environmental impacts in their models than the social impacts on indigenous Yavapai Indians. After all, how does one quantify the value of ancestral homeland or sacred space? Codesigners working in foreign contexts may rely too heavily on quantifiable factors at the exclusion of less quantifiable but vitally important ones. In the case of the Orme Dam, Espeland's New Guard attempts deal with this issue by appealing to rationalism through "commensurability." In principle, codesign deals with the issue by incorporating diverse voices in important decisions. However, this lofty, democratic ideal may be much more difficult to achieve in practice (Y. Lee 2008; Andersen et al. 2015).

Should this expectation prove true, we will see that the design team has great difficulty balancing the desires of disparate stakeholders. For example, it is possible that close partnerships with like-minded stakeholders may come at the expense of collaboration with indigenous groups. While no project can be all things to all people, codesign's ethos of democratic collaboration may be uniquely adept at disguising such a shortcoming. The prioritization of some groups and marginalization of others may happen subtly, behind an appearance of user-centered, locally-driven collaboration.

RESEARCH CONTEXT

Brazil

The town of Itacoatiara lies three treacherous hours' drive from Manaus and is home to about 90,000 people, though it feels much smaller due to the portion of that population that lives on jungle farmland outside of town. The main street through town, Avenida Parque, is filled with mototaxis—mostly young, mostly male entrepreneurs with small motorcycles that they use to carry passengers for a small fee—and pedestrians, who use the broad, tree-lined walkway down the middle of the two-way street to stroll or perform aerobic exercises. At any moment, the friendly hum of Avenida Parque can be suddenly disrupted by an abrupt—sometimes violent—downpour that may last fifteen seconds or several days.

Itacoatiara overlooks the Amazon River. The town has grown to the water's edge, and numerous slums have formed in low points where flooding is more frequently a problem. Many of the region's poor, however, live in the jungle surrounding the town, where they farm to feed themselves and to barter with neighbors. Some sell their products in local street markets.

According to some local farmers, one of the greatest challenges to agriculture is actually the ease with which plants grow. Farmland in Amazonas is so dense with jungle vegetation that when farmers rest one piece of land and cultivate another (Amazonian farmers are only allowed to farm 20% of their land at any given time) the resting land is quickly populated with lush, jungle vegetation. Crops often grow with ease, but clearing land is arduous work.

Mandioca Farming

Mandioca, most commonly known as *cassava* outside of Brazil, is a type of starchy tuber that has long been a major staple of the Amazonian diet, eaten in some form with almost every meal. Brazilians distinguish between two different types of cassava: one they call mandioca, affectionately nicknamed *mandioca brava* (angry mandioca). The other they call macaxeira, which is confusingly described at times as *mandioca mansa* (mild mandioca). Despite being poisonous with cyanide if unpeeled and uncooked, and notably tougher than macaxeira, mandioca is conclusively preferred over its milder sibling in Brazil because of its distinct flavor and rich, yellow color. It is most often peeled, ground, and roasted to produce farinha de mandioca, which translates literally to "cassava flour" but bears little resemblance to flour at all. Rather, farinha is a hard, granular substance (like a starchy, yellow Grape Nuts cereal) that is sprinkled over fish in Amazonas as universally as ketchup or mustard are spread on hamburgers in North America. In addition to farinha, mandioca is used to produce other foods, as well— for example tapioca can be made from strained-off liquid starch, and a sweet cassava cake is often made by mixing wet farinha with coconut and other ingredients and roasting it in a banana leaf.

According to local authorities, the Brazilian state of Amazonas should be one of the world's top producing regions for *farinha de mandioca*. However, regional production is insufficient to even meet local needs. Many locals buy one-kilo bags of farinha at the supermarket where it is shipped in from more developed regions of Brazil—an affront to many who take pride in local agriculture.

This indignity led a small group of producers from a local farming cooperative to organize their efforts toward modernizing and re-legitimizing the local industry. On a jointly-purchased piece of land, they planned to first grow watermelon to turn a quick profit, and then use that profit to build a state-of-the-art farinha production center. Their operation would apply the latest science-backed techniques and technologies as taught by regional and national agricultural agencies. Other producers in the region could bring their crops to the center to make farinha (instead of making it at home), or they could sell their crops for the group to use in their operation. If successful, the project would be profitable for the core group, would pave a path forward for local producers, and would re-legitimize Amazonian farinha on a national scale.

Through a mutual contact in Itacoatiara, the farming group was connected to a small team of design engineers from a North American university that had previously done work in the region. The engineering team, determined to make social sustainability and cultural responsiveness central to the project, decided to use this opportunity to attempt what they called "codesign."

Engineering Lab

The engineers studied in this ethnography are of a peculiar kind, one deliberately focused on the welfare of developing-world communities. They wear many hats—engineer, scholar, designer—which seems to afford them freedom to pursue somewhat unconventional undertakings. These undertakings provide opportunities for grants, publications, and patents, as well as capstone projects for the engineering graduate students. The team's projects address a wide range of basic human needs and social initiatives, centered around the notion that people are best helped by empowering them to solve their own problems and that solutions can be optimized for the greatest possible benefit. Discussions with the team frequently touch on the unorthodoxy of engineers studying social impact and on the inadequacy of the engineering tools and practices currently available to deal with such impacts. Yet the team has reason to believe that its efforts to blaze new trails are not entirely in vain. For instance, a recent publication from the team in a major engineering journal was the most downloaded article of that year, signaling a growing interest in the social impacts of engineered products.

Participant observation in weekly lab meetings comprised a significant portion of my field research. Most weeks, a team of five to ten individuals, mostly engineers with a few invited social scientists, gathered to discuss various research projects that the group was involved in. These ranged from product design to international development, with special attention paid to the social impacts of engineered products. Each member of the group had his or her project of focus, and meetings would typically consist of each person providing an update to the group and, if needed, soliciting help from the others. It was not uncommon for an entire hour-long meeting to be occupied by the discussion of a potential social impact or how to measure a particular variable.

The majority of weekly meetings and interviews with the engineers took place in the team's lab, which sits in the new Mechanical Engineering building of a private North American university and is filled with computer stations and miniature versions of various design prototypes. In one corner is an open meeting area with several oddly shaped chairs facing one another, and in the opposite corner is a conference room where approximately sixteen office chairs are spaced around a string of tables. One long wall in the conference room is occupied almost entirely by white boards, which are frequently put to use. At the front of the room, a large monitor faces the arrangement of chairs, equipped with "casting" software so participants can wirelessly display their own screen for everyone to see.

The codesign project was one of several projects being conducted by the research group. It was led by a PhD candidate whom I will call Peter, under the direction of his advisor and the research group's director, whom I'll call Dr. Marcus, Ph.D.. Numerous other engineers from the lab participated at different stages, as did the members of the Social Impact research team, including myself. As the team began preparations for an initial design trip to Brazil, I was asked to join as a sociological consultant.

METHODS

Meetings and Interviews with Engineers

For approximately one year, I gathered interview and observation data as part of the codesign project. I met with the engineers, about once per week on average, to discuss the project, consult on challenges, and review the ongoing design process. Almost all meetings took place in the engineering lab. With consent, I took detailed fieldnotes in each meeting, noting topics of discussion, communications with local stakeholders, design issues, cultural and social factors, and numerous other matters relating to the project. I also held regular interviews with both the team's director and the project lead.

Site Visits

I accompanied the engineers for two site visits to Itacoatiara and Manaus, Brazil. The first took place in May of 2019, and included approximately two weeks of observation, interviews, and interactions with locals, as well as some design activities such as ideation and prototyping. Interviews and observations from this trip were conducted primarily as user research, but became relevant to this ethnography and have been included as data. These "user interviews" were conducted using a game that explored the eleven social impact categories used in prior research (*cultural identity*, *paid work*, *gender*, *family life*, *networks and communication*, *health and safety*, *population density*, *social inequality*, *crime and conflict*, *education*, and *human rights*).

I conducted thirteen interviews with a total of fourteen people (one of the interviews involved a mother and daughter together) including eight females and six males. Approximately half of the interviewees were considered by the group to be ‘producers’ and the other half considered ‘consumers’ of farinha. We acquired our sample of interviewees through our collaborative network in Itacoatiara purposively sampling according to age, gender, and relationship to farinha production. Quantitative results from the game provided early insight for the design of the mandioca peeler, but the open-ended structure of the game also encouraged locals to express their views regarding a wide variety of social impact areas, resulting in rich qualitative data.

During the first trip to Brazil, the engineers gathered drone footage, three-hundred-sixty-degree GoPro footage, soil, water and electrical tests, and local farinha market statistics to provide contextual data.

The second trip to Brazil centered much more heavily on prototype testing, and included eleven days of observation and numerous informal and semi-formal interviews. Most interactions were recorded using a digital audio recorder and transcribed afterward. Nightly conversations with the engineers revisited themes that had come out during the day's observations.

Additionally, each of us recorded a video diary entry on a GoPro for each day of the trip, with very few exceptions. The unstructured nature of these entries served to highlight what had been most relevant each day from each person's perspective.

Sampling for interviews with locals was opportunistic but purposeful. The trip was organized to facilitate interactions and interviews with indigenous and non-indigenous, rural and urban, producers and consumers, as I had carried out much of my research thinking along these lines. I found, however, that distinctions between each group were much more porous than my framework allowed for. As will be discussed in a later section, I found that virtually everyone in the Amazonas region is both indigenous and non-indigenous, both rural and urban, both a producer and a consumer. While this required greater flexibility in my sampling, it also proved to be one of the more significant findings of my research.

This ethnography examines the experiences of one codesign project undertaken by one team of engineers. The generalizability of such a case is limited. However, the experiences of these engineers may be suggestive of projects conducted by other practitioners around the world. For example, this team struggled to access local indigenous populations. Other projects may, similarly, struggle to serve subgroups that are culturally or geographically more remote than others.

Coding and Analysis

After our first trip, I coded my observation notes and interview transcripts for themes using NVivo software. For example, I identified early patterns by coding for such things as “discussion of cultural factors,” “quantification,” and “communication with stakeholders.” Patterns that emerged in this stage helped focus my ethnographic efforts during my remaining time with the team.

Following the second trip, as the study came to a close, I performed three additional rounds of coding using Microsoft OneNote. In the first round, I organized my data chronologically and by data type (meeting notes, interview transcripts, fieldnotes, personal journal, and other). In the second round, I compiled key themes into one compendious coding scheme. Finally, in my third pass through the data, I applied the coding scheme using the program's search tags system.

RESULTS

At the time that the team started the mandioca peeler project, little had been published about how to carry out successful codesign. It may be, in part, that the most vocal proponents of codesign resist formalization. Whether because of its relative newness or its intentional ambiguity, the "process" of codesign might better be described as the "intention" of codesign. To that end, the engineers in this study explored a wide variety of research and design activities in the name of "creating positive social impacts," questioning whether each qualified as "codesign" and discussing what it means to share the decision-making role with one's user. These activities spanned two trips to the Amazon with a year of product development in-between, including Skype calls, prototyping, participant observation, guided walks through indigenous jungle lands, and more. Some of these activities, the group decided, are unique to codesign and others are just good design practice. The portion of the project covered in this ethnography ultimately culminated in a day of field testing alongside codesign partners where the question of what "counts" as codesign reached its point of greatest salience.

The results section is laid out in narrative format with events loosely grouped by themes. Limited analysis is provided throughout, with more extensive analysis in the discussion section that follows. In the narrative, I distinguish between three separate logics that became apparent during our initial product development research. These include an engineering, a modernizing, and a traditional logic. Second, I show how tension between these different rationalities may undermine some of codesign's collaborative aspirations. For example, the apparent irrationality of traditional stakeholders became extremely difficult to reconcile with the engineering logic's imperatives of efficiency, rationality, and measurability. Third, I show how the engineers ultimately must face the pull toward a more typical designer-client relationship. The symbols and ceremonies of codesign provide some resistance against this tendency. Fourth, I show how codesign is a way to transform the engineering logic toward a more culturally sensitive one, providing some empirical evidence for what some scholars have called institutional entrepreneurship (Maguire, Hardy and Lawrence 2004). I discuss how a focus on institutional entrepreneurship could, however, shift attention away from the very real impacts of international development work.

Co-designing a Mandioca Peeler in the Amazon: Two Logics Emerge

In this section I introduce the mandioca peeler project and explain briefly how it got its start. Then I introduce two logics. First I discuss the *engineering* logic, which focuses the engineers' attention on mechanical, quantifiable factors. Second, I describe a *modernizing* logic held by a number of the project's most influential local collaborators. These two have significant overlap, which makes collaboration easier, but they also have certain key differences that I discuss.

Travel to the remote Amazonian town of Itacoatiara is anything but convenient. Generally speaking, two full days of travel are required from start to finish. The flight to Manaus, which is often changed or canceled last-minute, typically lands sometime around one o'clock in the morning, local time. After a short night's sleep and the acquisition of a rental car, the treacherous drive to Itacoatiara begins. The narrow, jungle road is essentially as much pothole as pavement, and even if you manage to dodge a hole, you still must dodge other cars that are dodging holes of their own, none of which appears to slow anyone down. Much of current global development engineering takes place in such remote locations.

In May of 2018, Peter and another engineer from the university social impact research team, already in South America for a study abroad, took the opportunity to visit Itacoatiara and search out potential global development projects. Because of past work that the team had done in Itacoatiara, the two were able to utilize an existing network to explore potential projects. One local contact named Franco, a virtuosic but disorderly handyman, introduced them to Alberto, the head of a local, nonprofit farming cooperative referred to as the "sindicato." Alberto and the engineers discussed several possible projects—a fruit pulp separator, a cassava (mandioca) root peeler, a fishery. By the following fall, the mandioca peeler had gained momentum as the group's focus.

Engineering logic. Observations about the engineers on this team cannot necessarily be generalized to the broader field of engineering. Some features of their work are certainly unique, such as the fact that they are both practitioners and scholars of their discipline. However, they generally operate with a specialized, mechanical framework that I call the engineering logic. Several things stand out about the way they work. First, the engineering logic places high value on pursuing clearly-defined outcomes. When the path forward remains unclear, it is typically attributed to vague objectives. Second, measurability is key. Inputs and outputs must be measurable to be included in a model. Relevant factors must be quantified in order to discuss their relationships to other relevant factors. Ambiguity is accounted for in some cases with sophisticated uncertainty models, but is avoided where possible. Third, the world can be broken into systems and subsystems. If something doesn't fit into the engineering framework, it may be externalized to a separate system—a black box of the factors the engineer's model can't (or perhaps shouldn't) manipulate. However, in many cases the externalization of these factors seems to be temporary, as the engineering logic holds at its core the notion that virtually all factors can be modeled if resolution is high enough.

Because these engineers are also scholars of their discipline, publications are as valuable a currency as patents. The scholarly part of their work encourages them to push the boundaries of what their discipline can encompass. In contrast to many other kinds of engineering, design is also a key facet of the work these engineers do. Their work is much more aesthetically-oriented than, say, a NASA engineer. Both the scholarship and design aspects of the engineers' work help define their unique engineering logic.

At the outset of this study, the engineers expressed their interest in making this project radically more collaborative than would be typical for global development engineering. Traditional engineering projects tend to follow a distinctly "designer-client" format, which the engineers on this team frequently call "over the wall" design. During one codesign discussion, Dr. Marcus wondered if having more people involved in design decisions would lead to products that can benefit more people in new ways. Past projects, he explained, had relied too heavily on the engineers' own expertise and sometimes failed to produce the desired impacts. By collaborating more closely with stakeholders, the project may have longer-lasting positive impacts and more fully avoid negative ones.

However, for reasons that will be explored in detail, collaboration across disciplinary, cultural, and geographic barriers is far from straightforward. One such complication is the fact that some stakeholders in Brazil have more in common with the engineers. Alberto and the other core collaborators, like the engineers, appear motivated by a modernization imperative different from the engineers, however, they are notably non-technical. I therefore describe them as favoring a "modernizing logic."

Modernizing logic. Individuals we met who embody the modernizing logic have several things in common. First, they have favorable views toward Western ideals. For example, many point to the regulation and cleanliness standards applied in the States when discussing the need to modernize farinha production. Second, these individuals appear highly "rational" by being numbers-driven, organized, and systematic in their efforts. Farmers with a modernizing logic plant their crops in straight rows and care for them methodically, seeking to maximize efficiency. Third, they tend to be notably less concerned with preserving what came before than they are with pursuing newer, better ways of doing things.

Many of these individuals operate in a political or economic framework. For example, Alberto's role as the head of a rural farming cooperative carries distinctly political elements, such as regional pride, coalition-building, and reliance on political capital. He and others similarly prioritize economic factors, such as business growth, entrepreneurial opportunity, wealth generation, and market advantage.

Preparing for the First Design Trip: Making Room for Culture and Codesign

In this section I describe the formation of a collaborative framework, which the group sometimes treats as a *codesign* logic. Then, I explore the cultural significance of mandioca, including an indigenous myth about the plant, and in so doing establish a *traditional* logic that is often at odds with the engineering and modernizing logics. This makes it difficult for the engineers to collaborate with traditional stakeholders, and it is often unclear how they might incorporate traditional perspectives.

Cross-border engineering projects commonly take years to carry out. Once a potential project has been identified, extensive background research must be conducted, expectations must be set, and preliminary design work begins, often involving travel into the field to prototype and gather data. For the mandioca peeler project, first steps included researching mandioca production and local culture, as well as holding periodic video calls with Alberto to lay the groundwork for collaboration. Dr. Marcus asked me to join the project at this stage to help research relevant social and cultural factors.

The goal in this early stage, Peter explained, was to "teach Alberto a little about the design process and what we hope to accomplish before, during, and after the trip to Itacoatiara." I view this as an effort to establish a “codesign logic,” a shared space wherein both parties can shed their traditional roles and pursue joint discovery. This is a deliberate departure from the conventional designer-client dynamic that would likely take hold in a development project of this kind. For example, one call included the following Statement of Purpose, written by Peter with the help of the research team:

> We have found in the past that projects done in other countries have failed when they do not include people that have knowledge of the local context and fail to understand the needs of the customers. Our goal in this project is to have a lasting, ongoing social impact on farmers and other people in the Amazon region. We would fail if our products go unused or underutilized by your farmers. We hope that this project will serve as an example for future engineers working with local people in different countries. We want to learn more about the process of designing products with people in different countries. In our trip, and in future trips to Itacoatiara, we hope to collect information from the farmers on how they do their work, live, and interact with you and the broader economic players and to use this information to create better products.

By explaining the rationale, intentions, and past experiences of global development engineers, Peter invited Alberto (and subsequent others) to take on a shared vision, a new approach. He articulated certain shortcomings of the traditional engineering framework, and identified crucial new values, such as "ongoing social impact" and "understanding." He attempted to set a tone of empathy and collaboration for the project.

Although the Statement of Purpose was not directly referenced in any significant way, and it may not have had a lasting impact on the Brazilian collaborators, the ideals outlined within it did remain central to how the engineers approached the project. Toward the end of the project, symbols like this statement provided a stake in the ground to which the project was tethered, helping the engineers avoid certain pitfalls of “over-the-wall” design.

In addition to communication with Alberto, the group began formulating a research plan. Previous publications (Rainock et al. 2018) had identified eleven categories of social impacts for engineered products. The team determined to use these categories to define, prioritize, and quantify the preferences of local stakeholders. Many of engineering’s most useful tools rely heavily on quantifiable data. A survey would be most easily incorporated into the engineers’ models and would provide the highest number of commensurate responses. However, the subtleties of a foreign culture and the intentionally ambiguous nature of codesign do not lend themselves particularly well to survey research. Exploratory, qualitative research would allow us to better conceptualize our research on local terms, but would be difficult to incorporate into engineering models. Unable to find a balance between the two, we suspended our decision about data collection methods until arriving in the field.

The cultural role of mandioca. In Brazil, a noteworthy effort to modernize domestic agriculture is currently being led by EMBRAPA, a state-owned agricultural research agency (its name essentially stands for Brazilian Agriculture Research Corporation). One of the best resources on mandioca culture available prior to our trip was a video made by EMBRAPA (Nova Amazônia 2013). I discuss it here because it introduces us to a traditional logic and portrays the conflict between traditional and modernizing stakeholders. The video celebrated the cultural significance of mandioca and the hard work that goes into its production, but lamented the underperformance of regions like Amazonas where production is outdated and inefficient.

The video tacitly introduces two different views of mandioca. One is depicted as a highly rational pursuit of productivity, efficiency, and abundance, the other an irrational but culturally significant affection that traditional producers have for their work. For example, the video describes the plant as "motherly"— mandioca agriculture is accredited to the matriarch of a household (though the whole family is needed for the time-intensive task of peeling each root, which is often done with little more than a rusty blade). To emphasize the point, a tiny, elderly woman is shown moving through her field, heaving large mandioca roots from the ground as she explains that she learned the farinha-making process from her parents and will now pass it on to her children and grandchildren. In contrast, a man in an EMBRAPA cap and a shirt that reads, "Projecto Revitalizaçao da Cultura da Mandioca" ("Mandioca Culture Revitalization Project") explains, "People talk about this as a rustic culture, but it also has its problems. So it's also good to know how to navigate that culture, so that farmers can also not lose their production." He goes on to say that local farmers are only producing around three to six tons of mandioca per hectare, and that EMBRAPA's studies have achieved more than twenty tons per hectare. Numerous advancements that have led to such remarkable productivity are juxtaposed with the "rustic" woman, working in her small casa de farinha—an outdoor kitchen, of sorts, roofed with corrugated tin and populated by a makeshift grinder (to pulp the roots), a pulley and lever press (to squeeze liquid from the pulp), and a large cast iron pan with an open fire underneath (to cook out deadly toxins). A variety of farm animals roam in and out of the farinha house. The indigenous culture that had been celebrated just a few moments earlier now seems quaint and cumbersome. A hand grinder that has been precariously mechanized using an old washing machine motor looks ridiculous against a backdrop of sterile laboratory machines.

Still, the woman represents a common way of life in the region. Many rural farmers are reluctant to adopt EMBRAPA's findings, opting instead to follow long-held traditions. They have a very different relationship to the land than that of a corporation. The woman in the video explains that her relatives didn't want her to go out and live in the jungle. "I always liked the jungle," she tells the camera, "so I married at seventeen and dragged my husband out to the jungle with me." He had since died and she had gone on to work the land alone. She describes her relationship to mandioca since his passing as a "motherly" one. When contrasted with the efficiency and productivity of EMBRAPA, this traditional, familial relationship to mandioca is so pronounced that it reveals a third, "traditional" logic. This is comprised of stakeholders who aren't necessarily averse to modernization, commerce or technology, but simply aren't particularly motivated by them.

Traditional logic. Like the modernizing logic, the traditional logic encompasses several different frameworks that have certain things in common. For example, an environmentalist logic, a community logic, and an indigenous logic could each be examined in detail. However, for the sake of this ethnography, each of these frameworks had in common a focus on traditional ways of life that contrasted that of the modernizing logic. These individuals often saw farming as a way to subsist, to support their community, and to connect with their heritage. They weren't necessarily averse to mechanization, producing a surplus, or adopting new technologies—but they simply weren't as motivated by them as their modernizing counterparts.

One crucial aspect of the traditional logic in the Amazonas region is evident in the unease with which existing engineering tools account for traditional preferences and perspectives. While actors embracing a modernizing logic value measurable indicators much the way engineers do, those with a more traditional logic hold values that are strikingly more difficult to model numerically. Stories, myths, traditions, beliefs all resist the quantifying imperative of good engineering work, thus making it especially difficult to include traditional factors in decision-making models.

The myth of mandioca. The group knew that a socially sustainable product would necessarily be responsive to the local culture. Early in the project, the team became aware of a mandioca myth that seemed particularly noteworthy because it demonstrated the cultural significance of this ubiquitous crop. According to De Almeida and Portella (2006), the Tupy tribe of the Amazon told of a chief's daughter who became pregnant. The chief demanded that she name the child’s father, but she refused, denying him his vengeance. The chief decided to have her killed, but was stopped when he dreamt of a warrior with skin as white as the moon who told him to believe his daughter, that she was innocent and would bear a "great gift" to the people.

As the story goes, the woman gave birth to a moon-white child that she named Mani. The child was quickly able to walk and speak wisely, and she drew doting spectators from all of the neighboring villages. Shortly after her first birthday, however, Mani died suddenly, without any sign of pain or malady, and the now broken-hearted chief entombed her body in his hut.

The girl's mother poured water on the grave each day. After some time, an unfamiliar plant grew where the girl's body lay. The plant had a white root that could be cooked and eaten to renew the tribe's strength. They called the plant manioc (*mandioca*), which means "the house of Mani," and it became the staple food of the Amazon region.

For the design group, the myth of mandioca was a reminder of how even "irrational" factors could be supremely important. The team anticipated that some locals would resist new technologies that were seen as detracting from this heritage. However, it remained unclear how such factors might be influence specific mechanical aspects of the machine. Conversations routinely referenced how "traditional engineering" lacked interest in cultural factors, and yet there was no obvious way to incorporate them into the design work. Discussions around the topic highlighted the tension between modernizing farinha production and preserving local customs.

Trip 1: Making Sense of the Local Context

In this section I show the different logics in action, including tension between the modernizing logic and its traditional counterpart, as the team gathers data to inform the mandioca peeler's design. For example, I discuss how the group's interactions with agricultural experts at an organized "field day" reveal resistance among rural farmers to adopt science-based farming practices. A later experience making farinha with traditional methods is personally impactful but difficult to model quantitatively. Finally, I describe a series of gamified interviews that the engineers and I used to gather both quantitative and qualitative data about the possible social impacts of the machine. These three stories show how the modernizing logic, quantitative data, and priorities like "efficiency" are much easier for engineers to account for with existing tools than are the traditional logic, qualitative data, and priorities like "education."

In May, 2019, Dr. Marcus, Peter, an engineering student named Thomas (also a pseudonym), and I traveled to Itacoatiara for the "opportunity and concept development" stage of the project. Alberto, the head of the rural farming cooperative, met us at his organization's headquarters—a small, concrete building of white and green that sits overlooking the Amazon River.

Likely in his late forties or early fifties, Alberto is not particularly technical, nor is he an experienced farmer, but his charm and his intelligence make him a skilled flag-bearer and a quasi-political figure. He and his organization are the main source of support for rural producers in the region, a fact made all the more salient by the negligence of municipal leaders.

While in Brazil, the team had several opportunities to witness farinha production firsthand. Most mandioca matures in a span of approximately seven to twelve months. The plant is hacked off a few inches above the ground using a machete, and the stump is then worked back and forth to loosen the soil. Once sufficiently loose, the whole thing is heaved out of the ground and several bulky roots resembling bark-covered sweet potatoes emerge. These are then chopped off about an inch into the root (this part of the root closest to the stem is woody and unusable). The stem is then either discarded or chopped into short segments that can be planted horizontally in the ground to sprout a new plant. To make farinha (the most common use of mandioca), roots are peeled, soaked, and ground up. The granular mass is then pressed, sifted, and roasted.

We noted that most rural, subsistence farmers tended to plant two stem segments together in each hole, even though experts insist that the two plants compete for nutrients and neither is maximally developed. The team thought that this might be somehow related to the indigenous mythology, but none of the farmers we interviewed, rural or urban, seemed familiar with the tale of Mani. Likewise we found persistent confusion regarding how much peel must be removed from mandioca root before processing. All agreed that the outer, bark-like peel must be discarded, but a thin, inner peel is sometimes left partially intact by rural farmers. Agencies and agriculture organizations insist that this must be removed entirely. Failure to do so may have health implications and will drastically reduce the perceived quality of the product. Grocery stores, for example, won’t accept nearly any of the locally produced farinha because of these impurities and the conditions in which it is produced. Hygiene standards alone rule out virtually every home-based operation, and yet few farmers have adopted expert advice on any of these issues.

EMBRAPA field day. In order to familiarize ourselves with the substantial modernization effort being mounted in the region, the team attended an EMBRAPA-sponsored field day, where we met another key collaborator. Dozens of farmers attended the event where they were trained on agriculture practices generally and the emerging coffee industry more specifically. The event highlighted the extensive work that EMBRAPA has done to disseminate science-backed farming practices, all with limited success. Researchers from EMBRAPA described to us the resistance they had faced when trying to share new farming practices with rural farmers who seemed set in traditional ways.

At the event, we were introduced to Manoela, a powerhouse of a woman who had recently established an impressive, new farinha operation in neighboring Tefé. Alberto invited Manoela to become a member of the codesign collaboration for her expertise in high quality farinha production, as well as her valuable experience legitimizing what had been perceived as a backward local industry. What's more, her project in Tefé had managed to mechanize many aspects of farinha production, but no suitable peeler had been found. Her frustration with the existing options made her one of the team's most authoritative resources while designing the machine.

EMBRAPA, Manoela, and Alberto, became some of the team's most reliable sources of information, and the latter two were considered the main codesign partners for most of the project. It was not difficult to distinguish between their approach and that of the many farmers who refused to adopt productivity-enhancing reforms. It is also unsurprising, perhaps, that

Manoela and Alberto became the team's most central collaborators, because of the congruence between the modernizing logic that they favored and the engineering logic held by the team. For example, individuals with a modernizing logic, like the engineers, prioritized measurable progress toward the goals of efficiency and higher production rates. Shared understanding of this kind greatly alleviated the difficulty of cross-cultural collaboration.

To some degree, the engineers recognized the potential for blind-spots to emerge due to the modernization logic's centrality. In one post-trip conversation, Dr. Marcus explained that "maybe one characteristic of codesign is having many players with different views about how things should be." Peter agreed, stating that we had learned multiple ways of doing things. "We learned from EMBRAPA and from Manoela that there is a best way but that doesn't mean that people are always doing it that way." One farmer we know well, he noted, "is planting them random, not in lines to make sure that you have the most optimal density of plants in an area." Even while acknowledging differences in preference, however, a clear distinction persisted between those who preferred the "best" way and those whose approach was less "optimal."

Making farinha. Later in the first design trip, the team was given the opportunity to participate directly in farinha production, which provided rich, qualitative insight. Memorable, enriching experiences like this were impactful on a personal level, but it was often unclear how to incorporate them into design decisions using the tools of engineering.

Natalio, one of the co-op members and the owner of the farm where the co-op's land was located, led us in his truck down an impossibly long, Jurassic road. After driving through what seemed like millions of trees the road opened to a riverside compound with a handful of horses, several small huts (for storing crops), and a picturesque but simple house overlooking the water. A portion of the land would be set aside for the mandioca peeler and other necessary equipment.

A short boat ride upriver was the home of Natalio's father who still made farinha the traditional way. The team observed their process for several hours as they described each step. At times we were invited to participate in such activities as grinding the mandioca, pressing the liquid out, and stirring the roasting farinha, all while scraggly chickens and rail-thin dogs roamed the farinha house.

The hands-on experience was later referred to as a turning point for the project because of the depth it added to the team's understanding of mandioca agriculture. The feeling of heat from the oven as we leaned over with wooden paddles to stir the yellow mass brought new respect for the home-based producers that fill the region, but it also highlighted how much work is required for so little gain. As the surrounding society is globalized, this traditional life is increasingly untenable. Rural producers have survived for generations by growing mandioca and making farinha in homemade farinha houses. Now, higher-quality options are increasingly available at lower prices. Standards of hygiene and product quality in the formal economy are stricter, an effort to curb common maladies that result from poorly-made farinha. Manoela, for example, insisted that she wouldn't eat farinha bought from the unregulated, informal economy. Reliable customers for farinha vendors, like schools and supermarkets, have turned to non-local farinha for their needs, and rural producers are beginning to feel the effects of being left behind.

The game. One key focus of the group was to effectively account for the potential social impacts of the mandioca peeler. These included, for example, the effect the machine might have on *education*, *gender*, and *cultural identity*. The team hoped that a combination of research and collaboration would improve their ability to understand and then address these impacts. However, engineers rely most heavily on quantitative data, and potential social impacts proved extremely difficult to capture quantitatively. For example, the group used participant observation to gain an immersive understanding of the farming process. Experiences like visiting rural farms and making farinha by hand were difficult to translate into actionable data, despite being extremely impactful on an individual level. The group hoped that interviews with stakeholders would provide greater clarity about the form that the mandioca peeler should take and how it should be implemented, but while the interview method did explore a wide range of social impacts and even facilitated some quantification, the results often added more complexity than they clarified. Despite providing some numerical representation of stakeholder preferences, for example, the data did not often provide a value-free, objective path forward.

A main objective of the first design trip was to explore the preferences, priorities, and perceived social impacts held by local stakeholders toward a not-yet-designed machine. Interviews would provide a platform to thoroughly explore a wide range of social impacts, but would not easily produce the quantitative data that the engineers would need to model the machine's inputs and outputs. As had been previously determined, a survey would provide convenient quantitative data but would likely obscure more than it would reveal. The group ultimately compromised on gamified interviews—open-ended enough to explore complex themes but structured enough to produce quantifiable preferences that the engineers could incorporate into design models.

The game consisted of three bins (plastic cups), labeled "high," "medium," and "low" priority. The eleven social impact categories were represented in both written and iconic form on popsicle sticks, with the addition of an "other" category, and these were placed in the bins by interviewees as they discussed the relevance of each social impact category to farinha production. Concerned that our concepts might not translate adequately, Thomas and I "codesigned" the icons and verbiage with passers-by in the street and with hotel employees until we felt confident that the combination of words and symbols adequately conveyed each distinct category. In an initial practice interview, our participant gave all of the categories equally “high” importance. In one sense, this seemed a natural response, since the eleven categories were designed to capture as much of a product’s social impact as possible. None of them were likely to be wholly irrelevant. Therefore, in order to generate more productive conversation, we decided to limit each bin to four sticks. This, we found, forced participants to think and talk about the different categories in greater detail.

Interviewees ranged from consumers of mandioca products to full-time producers. Farinha is ubiquitous in Amazonas—nearly everyone eats the condiment daily, sprinkling it on fish, rice, beans, and other side dishes—so virtually everyone falls into at least one of these categories. While many working-aged adults consider themselves mere consumers of the product, a great majority of those we met claimed to have helped their parents or grandparents make it from scratch as youth. I came to think of this generation as being one step removed from the farinha-farming life—adjacent to and familiar with farinha production, but unlikely to pass this deep familiarity on to their own children.

The data obtained from gamified interviews showed great promise. Peter and Dr. Marcus listened in on one interview and were elated at the discussion it produced and that the interviews had so readily produced “requirements,” a crucial but difficult to obtain set of measurable objectives for the product’s design. The engineers explained that by discussing such a wide range of social impact categories with stakeholders we had identified the characteristics most important to each interviewee. These characteristics could be placed in a “requirements matrix,” a key tool of design engineering that establishes the most essential features of a product.

The game thus allowed the team to address the dual needs of qualitative exploration and quantitative analysis. The traditional tools of engineering rely on numerical data, and yet the study of social impacts often requires venturing into more ambiguous territory. The compromise became a focal point of the project, representing the tenuous but achievable confluence of the social and the mechanical. However, interpretation and implementation of the data presented new challenges. Months later, for example, we noted that *education*, one of the social impact categories, likely carried vastly different meanings for different stakeholders, and even for a single stakeholder at different times. In one setting, it could refer to formal education, as in "maybe this machine will liberate me to finish my education." In another setting, it might refer to on-the-job training, as in "maybe this machine will provide me opportunities for technical education." Such confusion clouded several other of the impact categories, as well. Distinctions between different meanings were not always clear. Peter attempted to incorporate findings by modeling social inputs and outputs, for example by showing how a particular feature of the machine would increase or decrease a particular social impact. Yet different definitions of words might have inverse implications. It was impossible to know whether the machine should produce more education by being more automated (formal schooling) or more education by being more hands-on (on-the-job training).

Early lessons. By the end of the first trip, several points became increasingly clear. First, the success of codesign would hinge greatly on reliable partners that could provide access and insight into the local context. Second, the individuals that appeared the most resonant and indeed the most perspicuous to an engineering logic were those with a modernizing logic. Third, this would mean that less-resonant voices, such as those with a traditional logic, risked being omitted from key considerations. The engineers showed some concern regarding this fact and discussed possible resolutions.

Codesign, if it can be done successfully, may offer one way to empower disadvantaged groups to advance on their own terms. However, such collaboration still requires an entry point for specialists from outside a culture to access the local context. This means identifying areas of congruence between the engineering logic and the logics of potential collaborators. Key figures like Alberto and Manoela have a definition of "progress" that is fairly compatible with the engineers' own definition. For example, both groups value efficiency, legitimacy, and productivity. Others, however, may define progress in terms of increased freedom, lighter workload, or the ability to pass traditions on to the younger generation. As noted by Peter, the groups have different values, "so the question is, whose values do you value?"

One potential solution that the group discussed is to collaborate most closely with gatekeepers like Alberto and Manoela, but to point their efforts toward the needs of less-accessible groups. Some of the more remote groups desire technological intervention but are too far removed from such resources, and are left to fend for themselves if unable to access outside help. To demonstrate this possibility, Dr. Marcus compared product design to a tree that can either have a single root (traditional engineering) or many roots (codesign). He explained that having more roots will strengthen the tree and allow it to support more branches, which represent the beneficiaries of the final product. Therefore, if the engineers were to focus their efforts on empowering Alberto to "do codesign" with rural farmers, it may even further strengthen the metaphorical tree. Such an approach would place more responsibility on Alberto, a local, to account for the needs of disparate stakeholders that he knows and understands. Furthermore, from an institutional logics perspective, this could potentially make the dissonance between the engineering logic and the traditional logic less problematic. Alberto could, ideally, serve as something of a mediator between two logics that have little overlap.

The possibility raised new concerns. For example, the social, economic, and political resources of the engineers may inherently place them in a position of power that cannot be convincingly subordinated to Alberto's role (Nieusma and Riley 2010). In other words, if the engineers are seen as the source of indispensable resources and legitimacy, as they were in this project, it would be difficult for the engineering logic not to take precedence.

Finally, the group became increasingly aware that modernizing forces seriously risk leaving rural, traditional, and marginalized groups behind. This fact presents culturally-conscious engineers with a complex, often contradictory challenge. They hope to provide marginalized populations with the tools needed to face a globalizing world, but in doing so may inadvertently take part in the globalization of those cultures. This concern is exacerbated by the need to rely on more modernization-minded locals to even access the local context. "To design is to make decisions," Dr. Marcus explained. "To design in the mechanical world is to make decisions about geometry and materials and manufacturing process." Including the client as a decision-maker is what distinguishes codesign from other design activities, the group determined. "Usually you'd just design something and deliver, but with codesign you have them as part of the design team." Who, though, gets included?

Development Stage: Putting the Data to Work

The development stage comprises the period of time between the first trip and the second, wherein the majority of design work took place. I continue the discussion of quantitative versus qualitative data. Then I demonstrate the tension between a designer-client relationship and a collaborative one—the first being an element of traditional engineering and the latter being the objective of codesign. Finally, when the project nearly dissolves, the engineers' role as scholars becomes more salient—even codesign failure can be a success if it produces new knowledge.

Shortly after the first design trip, an interesting new dynamic emerged in the engineering team. A sense of urgency immediately consumed the team's focus—to rapidly produce a prototype that they could unveil to Brazilian collaborators on subsequent Skype calls. This pressure to advance the project further illuminated tension between traditional engineering and codesign. The team recognized the substantial time requirements of analyzing transcripts and interpreting social impact data, and yet was compelled by the engineering logic to move the design forward at the pace expected for traditional engineering work.

As the engineers progressed on the machine, Peter recognized the ease with which the collaboration could become just another "over-the-wall" project. In one meeting, I asked him if the interview data had been important in his prototyping and design, to which he responded, "I want it to be important…it's important to me that it's important, but it's hard to say 'oh this is important so therefore the design needs to be like this.'" He explained that our interview transcripts were not particularly relevant to the mechanical decisions, but could be important for the more "abstract decisions."

The tension between a "designer-client" relationship and a "codesign" one pervaded many aspects of the project. For example, the urgency with which the team pursued an initial design looked much more like traditional design than a collaboration. Peter discussed the matter with me at various points, explaining that he felt torn between being a good engineer and a good collaborator. He said, "we could just go and make decisions but I've been holding it back so I can link it back to this stuff." A colleague added "And having them do it with you," to which

Peter lead agreed, “Yeah, that’s the co-design part, right? We could keep designing but we’re supposed to be designing it with them."

Even the team’s codesign partners in Brazil seemed torn between hands-on collaboration and deference to the specialists. The engineers often struggled to engage Alberto and others, explaining later that collaborators would simply agree with any proposition the engineers presented. Dr. Marcus later explained, “we were never going to ask the locals which screws we could use, but maybe we could’ve done more collaboration during the conceptual design stage.” Considerations like solar power versus the electrical grid, iron versus aluminum materials, or a standing versus seated user position may have been good opportunities to collaborate. However, weekly collaboration meetings (using Skype) had already become largely symbolic for the locals and, at least to a degree, for the engineers.

Even the elements of codesign that became merely symbolic, however, had an impact. Acknowledging that the team hadn’t yet found a way to fully collaborate with local stakeholders, Peter later said that the mere proposition of codesign greatly increased the degree of accountability and openness that the engineers felt toward stakeholders. The mere commitment to codesign provided, at times, an anchor against the tendencies of traditional engineering. Even symbolic check-ins with Alberto were helpful as frequent reminders of the non-mechanical side of the machine’s design. Peter explained that, at the very least, the collaborative aspirations of codesign pushed him to expand his scope beyond the nuts and bolts of the machine.

As the prototype moved forward, Peter made a concerted effort to include more of the social impact data in design decisions. He explained that engineers must understand the relationships between various inputs and outputs so they can manipulate mechanical features to produce the desired outcome. To do this, he created models depicting the eleven impact categories, each weighted according to their game results and connected by arrows of different colors. He had worked with other engineers to pinpoint the relationships between various factors. Some of the social impact categories, he explained, had been fairly intuitive to model, while others were much more difficult to unpack. For example, when the team struggled to dissect the social impact category of education, it became impossible to know how that impact related to any others. In one meeting, the research team spent some time debating the possible meanings of the “education” impact category. After a lengthy discussion, we decided to let the interview transcripts resolve the matter.

While the team’s qualitative data was extremely descriptive, it was ultimately difficult to fit findings into the engineering framework. Even after analyzing discussions of “education” in interview transcripts, conversations still frequently ended with "But how do I put that in my model?" or "How do we quantify that?" Different interpretations of education could not be easily quantified, but it was obvious that they should influence the machine’s design. Should the team, for example, design a machine that provides greater technical training or a machine that liberates people to return to school?

Sometimes, the engineers viewed codesign as a collaboration in building a system into which the machine would be placed. The machine itself was, therefore, not the subject of codesign and could be approached as a primarily mechanical problem. This approach allowed for a more designer-client relationship, and temporarily eased the burden of translating social factors into mechanical features. They could instead focus on the mechanical aspects of the machine. Their focus, however, would get disrupted when faced with socially-relevant design decisions. For example, when determining whether to create numerous small machines or one large machine, the group had to decide which social impacts were most important. A large machine would be more cost effective, but numerous small ones could increase accessibility, each approach corresponding to distinct social impacts.

At times, I felt tension between myself and the flow of the project because of my focus on messy, social factors. I strained against the tendency to quantify all qualitative data, and to ignore that which couldn't be modeled. Later, I came to recognize that my involvement was to strengthen the pull toward codesign, and that some degree of tension was, in fact, the goal. I was another stake in the ground, like the group's written commitment to codesign, stretching the project away from traditional engineering. One way this became evident was when I recommended that the engineers include some kind of "asterisk" in each model or diagram where they could note each seemingly relevant factor that hadn't been included. I would then refer back to the notes in discussions that otherwise may have focused purely on the model. Later, Dr. Marcus explained that having a social scientist on trips and in design discussions is a "perspective changer." Embedding an ethnographer in the team was a conscious decision that the engineers recognized would cause productive discomfort.

The end of codesign? In the summer following our first design trip, the team suddenly lost contact with Alberto and the other collaborators. Though uneasy about the lack of communication, the engineers saw this as an opportunity to focus their full attention on the mechanical aspects of the project.

Ultimately, the group learned that the group had experienced a rift—that Natalio, Valentina, and some other key members were no longer part of the group. Alberto offered some reassurance that he had a plan to move forward, but confidence in the codesign project waned. (It was later revealed that Alberto had withheld this bad news because he hadn't wanted to lose the confidence of the engineers. He had waited until he had a new plan before revealing the failure of the first one.)

Faced with the potential dissolution of the codesign team, the engineers relied on the scholarly aspect of their logic more than ever. For example, Dr. Marcus stated that codesign had never been the primary goal—the *study* of codesign had been. Even an abrupt failure could be considered a success if it provided new understanding.

Trip 2: Putting Codesign to the Test

In this section I discuss the return trip to Itacoatiara which, in some senses, marks the culmination of codesign. Technically speaking, the project continued after this trip. However, returning to Brazil with a prototype of the machine signifies a major milestone in the collaboration—the first tangible fruits to come from many months of labor. As such, the occasion brings to the surface many questions that had underlied the project, such as how to deal with conflicting stakeholder preferences, what activities qualifies as "codesign," and how concerned the group ought to be with downstream impacts of the mandioca peeler. The trip ends with a visit to an indigenous tribe that challenges many of the team's assumptions (as well as my own) about the role of technology in traditional life.

After several months and additional reassurance from Alberto, the group planned a return trip to Itacoatiara. The trip consisted of Dr. Marcus, Peter, me, and Dr. Marcus's father, John, a former shop teacher and expert handyman. Like the first trip, the stated objective on this trip was to obtain data that could be used in the machine's design and future publications. The difference now was that the team had a prototype, which had been all but completed just prior to the trip but would need to be assembled in the field. Peter's focus during the trip would be getting the machine assembled and functional, and to perform as many field experiments as possible to test its limits.

In particular, the trip presented the team with opportunities to further the machine's design in ways that could not be done in the university labs. First, the only mandioca available to the team thus far had been very poor quality, likely shipped in from Mexico and apparently coated in protective wax. Second, the conditions in the Amazon are impossible to replicate fully in a lab, such as the humidity, temperature, electricity fluctuations, and other variables. It would be crucial that we see the machine operate in the setting that would ultimately be its home. Finally, this trip would provide a key opportunity for the team's codesign partners to see and interact with the prototype in person. They had seen photos and videos during various stages of design, but would see the peeler in action for the first time during this visit.

By this time, I had already performed approximately ten months of ethnographic observation and interviews since the previous trip. I would use this as an opportunity to see the group dynamics of engineers, leaders, farmers, and others as they came together for this momentous occasion. I also hoped to perform additional interviews regarding the cultural significance of farinha and potential changes to the farinha industry. I wanted to know whether families valued the time they spent together doing the arduous work of peeling mandioca, or if they would prefer that the task be entirely automated. I wanted to know what, if anything, would change about their lives if new technologies were introduced. Would shrinking the farinha production process from three days to two (or more, by some estimations) liberate them to pursue other interests or responsibilities? Would subsistence farmers increase production and start a business? How would these factors influence the machine's final design and implementation? Would it even be possible for the engineers to include the information in their decision-making models?

Conflicting stakeholder preferences. Codesign invites stakeholders to be included in design decisions, but it's not always clear *which* stakeholders should be included, and what to do when preferences differ from one collaborator to the next. One of the greatest challenges in the mandioca peeler project was accounting for the needs of those included in design decisions (the roots of the metaphorical tree) but also others who might be impacted later on (the branches). This was particularly important because, as noted previously, the most central collaborators tended to espouse a modernizing logic that differed greatly from the traditional logic of others who may be impacted downstream.

In the months leading up to the second trip, the team came to recognize large discrepancies between stakeholder preferences, and dealing with conflicting voices became one of the team's greatest challenges. For example, some stakeholders prioritized access while others prioritized efficiency, each of which would impact the machine's design differently. Car travel provided valuable time to reflect on these difficult questions as a group. Underlying concerns were often vocalized and dissected during these hours, and the second Brazil trip was filled with conversation of conflicting stakeholder preferences and long-term social impacts. Peter pointed out the difficulty we had had accounting for the needs of rural farmers. Even if they don't realize it, he argued, our project could have detrimental effects on their way of life. Our friend Roberto (rural farmer) may be in favor of technology that makes his work easier, he observed, but in the end that technology could drive down the price of local farinha and reduce his bargaining power. Even if we could account for conflicting preferences, it seemed, we would still be unable to grasp all of the possible consequences of our work.

In another conversation, Dr. Marcus explained that the typical solution in design engineering was to listen to whichever stakeholder is paying for the project, that there is a hierarchy of stakeholders with the one footing the bill at the top. He explained that engineers typically favor stakeholder preferences according to that hierarchy but acknowledged the shortcomings of this model and the team's responsibility to find a better solution. He asked if the interview game from our first trip had provided any clarity regarding people's different values. Peter replied that we still had to decide who's values to value, "because you still have to make decisions and those decisions are going to respond to someone's values and not others."

According to both Dr. Marcus and Peter, engineering design typically responds to the values of a single client (or group of clients). Multi-stakeholder decision-making, on the other hand, presents a new challenge. The inability to rely on objective measures to resolve conflicting demands further complicates matters. Social impacts alone are difficult to translate into engineering models, but conflicts between the social impacts of disparate stakeholder groups makes prediction and calculation virtually impossible, at least with existing tools.

Tiago's farm. Just as Alberto and Manoela had become key collaborators, Natalio's replacement, Tiago, quickly became a central figure for the codesign project. In part, his importance is obvious—he is, after all, the owner of the farm where the project would attempt its rebirth. However, shortly after meeting the man, it was apparent that Tiago would be more than just a landlord. This was, in large part, because of this engineer-like approach to farming.

Shortly after our arrival in Itacoatiara, Alberto excitedly told us about Tiago, a humble, intelligent man with a piece of farmland not far from town. Tiago had already produced substantial fruit crops on his farm, giving him extra credibility. We asked if we could visit the farm, and Alberto excitedly agreed that we should go later that day.

As we pulled up to the farm, a large, shirtless man approached Alberto's car. After a few words through the window, he acquired a shirt and greeted us. Meanwhile, the engineers commented on the variety and organization of his many different plants. Alternating varieties populated each row in clear, straight lines. "He's got it all divided up and everything!" exclaimed one of the engineers. A homemade irrigation system and an old rototiller were both quickly noted, as well.

A tour of the farm reaffirmed Tiago's methodical (and modernizing) nature. For days afterward, the group referred back to his scientist-like curiosity and attention to detail, commenting on the confidence that he afforded the project that had just recently been floundering. Tiago showed us his method for dealing with pests, his makeshift nursery, and various other aspects of his operation. He gave us guava right off the tree, explaining how he had been buying up fruit from other farmers to make juice concentrate as a side business. He hoped to have enough productive fruit trees soon that he could continue the business self-sufficiently. When a sudden downpour began, he merely glanced at the sky and continued the tour, even slipping in a few words of English.

Like Alberto and Manoela, Tiago serves as a bridge between the engineering logic and the seemingly far-removed cultural factors that they are attempting to account for rationally. Symbols like an orderly farm and well-kept equipment have practical value, to be sure, but are more importantly indicators of common ground between Tiago and the engineers. A manicured farm may be more productive than a haphazard one, but not all of the farmers we met were particularly concerned with productivity. Some, like Roberto, are content to subsist on a sprawling patchwork of crops and jungle (sometimes indistinguishable from one another). To sacrifice additional time and effort in pursuit of more than one needs may seem absurd to such individuals. Someone like Tiago, however, visibly values productivity for its own sake.

Test day – managing expectations. The central event of the team's second trip was a day set aside to test the machine on-site. The team would run a series of tests, measuring a root, then peeling it, then photographing all sides to monitor the effectiveness of the peeling mechanism. The test day would also be a key opportunity to obtain feedback from the codesign partners. However, managing expectations soon became a major concern, demonstrating again the tension between codesign and the pull of a traditional designer-client relationship. From the perspective of traditional engineering, the unveiling of a prototype is a key opportunity to impress stakeholders and win their increased support. The collaborative ideals of codesign, however, reframe the notion of an "unveiling" as problematic—with enough collaboration, locals would ideally "own" the successes or failures of the machine as much as the engineers do, and the idea of "unveiling" would be irrelevant. This tension between the role of engineer and the role of codesigner is evidence of conflict between legitimacy in engineering terms and legitimacy in codesign terms—between the engineering logic and the ideals of codesign.

As the group prepared for the test day, a debate arose among the engineers as to how we ought to introduce the prototype to the group. One goal of the tests would be to push the machine to its limits, so eventual failure was a near-certainty. We wondered whether the collaborators would, like us, see it as a step toward success, or if their confidence in the team's ability to produce a functioning machine would suffer. One side argued that we should be careful not to fail in front of collaborators, or at least to lower their expectations, perhaps by introducing the prototype as a "data-gathering machine," designed merely to test out the idea of mechanize mandioca peeling. This argument envisioned the project as a series of graduating circles, with the designers in the inner circle, our collaborators in the next, and other users in the outermost circle. The other perspective argued for trust that, as co-decision-makers, our collaborators would react positively to failure, that they understood the purpose of the testing, and that true codesign required complete transparency.

The dilemma made explicit the tension between codesign's lofty ideals and the practical reality of expert designers working with non-expert clients. The team's local partners had been absent from much of the prototype's development, despite the engineers using tools like Skype to try to shrink the distance between the two groups. In fact, the very concept of prototyping seemed foreign to local collaborators. On the other hand, one of the main purposes of the trip had been to solicit honest feedback. If collaborating over Skype had been so unfruitful, weren't we obligated to make up lost ground now that we had the chance?

One member of the team referred to Alberto's lack of transparency several months earlier, when the project had been at the brink of implosion. After introducing us to Tiao he had admitted that he had withheld information about Natalio and Valentina's departure months earlier, that he had been afraid that the engineers would lose confidence in the project. Only once Tiao had agreed to join the project and to house it on his farm had Alberto conceded news of the earlier rift. By waiting until he had good news to cushion the bad, one engineer argued, Alberto showed a lack of trust in the codesign process.

As the test day approached, it became clear that at least some damage control would, in fact, be necessary. Alberto and Manoela were obviously excited to see the prototype, and had invited a number of people from the codesign group to be present. Further exacerbating the issue, it became clear that they intended to invite individuals from outside the group to attend. This meant that failed tests, for example, could lead to fast-spreading misconceptions about the state of the project. A lengthy conversation with the collaborators emphasized the prototype as a "machine for gathering data" and downplayed the test day as any kind of grand reveal. Dr. Marcus asked them to withhold judgement, and explained that failure was, in fact, the goal. We would not be successful unless the machine was pushed to its limits.

Dr. Marcus later expressed that, in the end, he hadn't felt as much contradiction between the two approaches as one might expect, but that he understood why some might. He had compromised between the two by mitigating the possibility of disappointment while also emphasizing transparency. Greater communication with stakeholders early in the process, he admitted, might have helped provide the correct vision for the prototype. This was an opportunity to fill in some of those gaps.

In principle, the ethos of codesign demands that collaborators be brought into the inner circle. In practice, however, this represents one of the most salient points of tension between engineering and codesign. The specialized logic of engineering required some compartmentalization to maximize its strengths, whereas codesign requires joint discovery throughout the process. In order to do their job well, the engineers must be allowed to be engineers. Yet codesign requires that they blur the lines between their role and that of the client. The engineers attempted to resolve this tension by *engineering* the machine but *codesigning* the system around the machine. They had focused their collaborative efforts on the factors surrounding the machine, such as workflow and business model, but kept the machine itself in their purview. However, the simplicity that this compartmentalization affords in the short term may undermine the ethos of codesign later. When the machine is eventually unveiled, stakeholders lack the context necessary to be true collaborators.

On test day, we took great care make the experience as positive for the collaborators as possible. We unveiled the machine only after everything was in place, kept stakeholders somewhat distracted while setting the machine up, and performed the easiest tests first.

Our codesign partners showed great interest in the tests and spent nearly a full day on site. They made several suggestions regarding the peeler, such as turning the grip arm a different way, shaping the blade differently, and simplifying the gripping mechanism. The engineers accepted each suggestion courteously but later told me that it was difficult not to push back. "The feedback we got maybe illustrated something that we didn't do very well," Peter later said. "Or maybe it's just something about codesign." A lot of the suggestions people had made had already been considered by a whole team of engineers beforehand. Rather than explain each of the mechanical reasons why an idea hadn't made it into the prototype, he had simply replied, "Yeah, we could give it a try. I think that's a good idea." The frustrating reality, he explained, was that everyone in the group didn't know what had already been done, and it wasn’t clear whether that was a failure of the group or just a codesign reality.

As the day came to a close, Peter became anxious about having performed enough “codesign” for the day to be considered a success. Torn between the need to perform as many tests as possible and the imperative to solicit feedback from collaborators, he told me that he felt like he "hadn't even done codesign yet." Some feedback had been given, but most were related to specific mechanical features that had already been considered. Little had been discussed of the social aspects, the usability of the machine, or the workflow around it. Peter had been so occupied performing tests that he felt he had missed the opportunity to interact with collaborators. I had recorded several conversations with the onlookers throughout the day, and I told Peter that I would happily share them. However, despite having completed far fewer tests than intended for the day, he left his post at the machine to discuss the machine with Tiago, the only remaining collaborator. Dr. Marcus, aware of the need for additional tests, grew increasingly anxious as the daylight faded and asked me to help complete the tests with the director while Peter "did codesign" with Tiago.

The Mura. The team had experienced difficulty incorporating the perspectives of those with a traditional logic into the machine's design. This meant that the needs and perspectives of some rural and many indigenous people may remain unaddressed. While the team never identified a clear way to measurably incorporate indigenous perspectives into the machine's design, participant observation once again improved the group's understanding of indigenous needs. It also provided better context for lingering concerns regarding indigenous traditions and the myth of mandioca.

One lingering concern that I had discussed with the engineers was whether the benefits of the project would extend to indigenous groups and others that are more geographically and culturally removed from the group. During one meeting with the codesign partners, I asked Alberto who would benefit from a machine once it had been realized on Tiago's property. He explained that rural farmers from the region would have access to the high-tech farinha house, and that the intention of the project was merely to pave a way forward for farmers interested in modernizing their production. The group, with Tiago as its face, would add legitimacy to the local farinha industry, but other farmers would benefit from the revitalization in a number of ways.

When I asked if indigenous groups would likewise benefit, he excitedly showed me photos of a nearby tribe and stated that, although he didn't know them yet, he had been contacted through a mutual friend—that a collaboration with the tribe was in the works. He said that he hoped they, too, would benefit from the new mandioca peeler, explaining that many of the most remote producers are completely at the mercy of brokers who buy their mandioca at various locations along the river. Some of these farmers, he explained, travel long distances with heavy bags of mandioca, hoping to sell it. When the middlemen offer an unreasonably low price, they have no choice but to sell or return home with the product. Either option is a loss. His goal, he explained, was to give them a place where they could come produce their own farinha, or to sell it to the group for a fair price.

As we discussed the needs of indigenous farmers, Alberto paused to make a phone call. Soon, he was introducing us to his aforementioned contact in the indigenous tribe, a stocky, tan man named Claudio. His square features looked like they could have come from indigenous ancestry, but he told us his parents were actually from Spain. He explained that he had spent four years living with the Mura tribe, and that he was considered a member of their family. By profession he was the president of IDAM, a local organization that helps indigenous peoples in the region gain access to needed help and resources, and his closeness with the tribes had been particularly useful. He and Alberto had recently begun exploring ways to bring rural farming resources to the remote indigenous tribes that had long been abandoned by local governments.

We asked Claudio about the tribe's view toward mechanization, to which he replied that the tribe wants advancement, but that they want it on their own terms. "They want a university," he explained, "but they don't want it in concrete buildings." They want English but they also want a resurgence of their native tongue. They want technology but they want to use it in their own way.

We made arrangements with Claudio to visit the nearby Mura tribe, an isolated group that only gets visitors once every two or three years. He explained that they were interested in the team’s work and were excited to meet us. The village sat on the banks of an Amazon River tributary, encompassed in dense jungle, and had to be accessed by a lengthy ride in a small metal boat with an outboard motor. After greeting a man in the wooden house closest to shore, we made our way through the small village toward the chief’s house. I noticed a young boy wearing a headdress made of small sticks, who turned out to be the son of the chief. The chief’s headdress was much more elaborate, covered in blue and red feathers and accompanied by jewelry of bones and shells. His traditional regalia were a striking contrast against athletic shorts and a polo t-shirt. Many others in the village were also dressed in well-used athletic clothing, though most were barefoot and many of the men were shirtless.

This amalgamation of Western and indigenous elements was manifested throughout our interaction, and Claudio's example of a university without concrete walls frequently came to mind. It became clear for the first time that my mental distinctions between indigenous and non-indigenous people in the region had been wildly inaccurate. I had anticipated an exotic encounter, likely necessitating an indigenous translator, and being welcomed into an inner circle of the select few who have seen this ancient way of life. Instead, we realized almost immediately that we were only a few miles at most from Natalio's father's home where we had made farinha the year before. Many of the structures were made of wood and thatch, but not wholly different from the homes we saw in town. Here, I realized, virtually everyone is indigenous just like everyone is a farinha vendor. Native and non-native, vendor and consumer, urban and rural, farmland and jungle—each is so embedded in the region that the absolutes have been replaced by shades of gray. Such nuance is difficult to grasp from outside the local context, and it highlights the importance of codesign's imperative to engage locals. Even the way an outsider categorizes different groups of people can be sorely misguided, an error that likely shapes much of the world's development work.

The chief, barefoot like the others, led us on a walk through the nearby jungle. He showed us how to drink the filtered water from a vine and which trees produce perfumes or pain-killers. He told me how they had carved their village out of the jungle, but that the jungle relentlessly tries to grow back. Persistent effort is required to keep it at bay. He explained that they've incorporated some jungle elements as domesticated food sources and that their children roam freely into the jungle (often barefoot), so they'll learn to navigate it.

As an ethnographer, the experience was strikingly poetic. The chief's description of their yin-yang relationship with the jungle—a bit of chaos in the order, order in the chaos—also seemed the perfect imagery for their relationship with modernity, as Claudio had explained days earlier. Much of the Mura's effort goes into keeping it at bay, but some elements are allowed in on the tribe's terms. The younger generation is allowed to explore, but always reminded where home is. They actively negotiate the space between old and new in a way we, as outsiders, had not fully anticipated.

At the end of our walk, I tenuously told the chief that I had heard of a myth regarding the first mandioca plant. Before I could finish my inquiry, he matter-of-factly said, "Yes, the story of mandioca. It was an Indian woman who died. She was called Manicoera. She was the first mandioca tree that existed here, for us. She was an Indian." I asked if that history complicates the idea of introducing new technologies into the farinha tradition. He smiled and said, "No, technology will help improve things for people. Mandioca will continue the same way…it will be planted in the same season, it will be harvested in the same season. Nothing will change. All that will change is the production, to be able to produce more." Then he abruptly paused to point out a strange-looking fungus on the jungle floor.

The chief's casual, unconcerned tone when discussing the possibility of major technological change highlighted the role of traditional actors in negotiating change. From a codesign standpoint, such a figure may have seemed inherently opposed to development work. However when empowered to make changes on local terms, such individuals display a nuanced approach to modernity that is seldom emphasized in Western discourse. The "hybridization" pattern of globalization (Embong 2011; Hassi and Storti 2012) provides a refreshingly nuanced take on international development and helps explain the way codesign could engage local stakeholders. Collaborative projects might better empower locals to modernize on their own terms while providing them the tools and resources necessary to do so.

DISCUSSION

Codesign is not so much a codified set of practices as it is a guiding principle or intention. The ideals of codesign include collaboration, joint discovery, and context-specific solutions (Sanders and Stappers 2008; Andersen et al. 2015; Simonsen and Robertson 2013). For engineers working across borders, however, the ideals are much more difficult to achieve than one might expect. Based on this ethnography of a codesign project in the Amazon, I make several observations connecting codesign to institutional logics, developmental idealism, and marginalization. First, the success of this codesign effort was sometimes hindered by conflicts between logics. I argue that the engineers navigated this conflict by changing the way they frame the collaboration and by outsourcing certain elements of codesign. Codesign presents an opportunity to stretch the engineering logic toward greater inclusion of social and cultural factors. Paradoxically, this was possible even in areas of codesign failure. Second, codesign as practiced in this project may have ameliorated some concerns raised by developmental idealism, but it appeared to have perpetuated others. Third, codesign provided these engineers with new ways to engage local stakeholders, but may have insufficiently account for the needs of marginalized groups.

Institutional Logics

Too many cooks: engineering vs. codesign. Codesign is a practice much more at home in design firms than in engineering labs. When dealing with matters of preference, user input is often relatively straightforward. A designer collaborating with stakeholders will take the needs and wants of a user and translate these into aesthetic and functional features. For the engineers in this study, however, the endeavor is much more a mechanical challenge than an aesthetic one. Mechanical factors reveal a much greater distance between user and designer, a distance which greatly complicates the notion of close collaboration. Stakeholder preferences in this codesign project were often not easily translated into clear, mechanical directives. In other words, practitioners of codesign are encouraged to elevate the user to the role of decision-maker, but when it comes to the mechanical aspects of a product (like the mandioca peeler), the ability of a non-technical collaborator to meaningfully fill such a role is greatly diminished.

At times, codesign seemed entirely compatible with engineering. Often, however, the two were noticeably at odds. For example, with very limited time to spend in the field, the group was frequently torn between working on the machine and meeting with local stakeholders. Ideally, the two activities would overlap—work on the machine would involve local stakeholders. But in practice it became clear that mechanical issues required their own time and attention, free of distraction. This meant that less time could be spent with locals. Furthermore, although the group recognized that not all of their work warranted collaboration, it was not often clear which tasks were tasks should be codesign tasks and which ones fell distinctly within the domain of engineering.

When faced with the decision between collaborative concerns and mechanical ones, the mechanical frequently took precedence. In some respects, it was necessary that they, as technical experts, focus their efforts on technical concerns. For example, on our second trip, we had hoped to have the machine fully operational within a day or two of arriving in Itacoatiara. Given the number of unknown factors inherent to in-field engineering work, it was somewhat unsurprising that the machine was delayed by several days—by day five the group was still discovering new problems that would make meaningful field-tests impossible. However, the normality of such complications in global development engineering only emphasizes the need to examine the consequences of such a challenge. In the case at hand, several activities involving local stakeholders were canceled or postponed. The team had hoped to involve collaborators at this stage, but it became clear that "too many cooks," as Dr. Marcus put it, would be counterproductive. The team instead streamlined the work effort, focusing more of their attention on their role as engineers and less on their role as codesigners.

The statement that "too many cooks" would be counterproductive may seem obvious, as it did at the time, but it raises the question: When is it acceptable to have other cooks? The comment highlighted the reality that some tasks fall outside of the domain of codesign, tasks that require a uniquely mechanical expertise—an engineering logic. To involve non-engineers would hinder rather than help the work. On the other hand, tasks that fall within the domain of codesign would benefit from the presence of non-engineer perspectives. However, at least for the engineers in this study, such tasks were extremely difficult to identify. In the absence occasions that obviously necessitated collaboration, the group was most comfortable focusing on their engineering work. It was their explicit commitment to the ideals of codesign that caused the engineers to actively seek opportunities to "do codesign," even if some of these instances were merely symbolic.

This pattern reflects the "decoupling" spoken of by organizational theorists (Meyer and Rowan 1977) and in numerous empirical studies (Delucchi 2007; Westphal and Zajaz 2001), but from a new angle. As scholars have well documented, conflicting institutional demands will likely lead to the decoupling of day-to-day activities from compliance. In this case, due to the technical demands of the project, the engineers often decoupled their work as engineers from their compliance with the ideals of codesign to which they had consciously bound themselves. More interesting, however, are the ways the engineers come to navigate conflicting logics, how they attempt to "recouple" engineering and codesign, and how they use the tension to stretch the institution of engineering toward greater awareness of social and cultural factors.

Navigating conflicting logics. The engineers navigated conflicting institutional logics in a number of different ways. First, some flexibility is allowed in defining codesign, and the engineers employed two different definitions of codesign. These shift the focus slightly and ease some of the tension from conflicting logics. Second, the engineers outsource certain elements of codesign, giving it a more tangible form and allowing them to focus on the mechanical side of their work. Third, the engineers used codesign to serve a broader purpose: to stretch the engineering logic. Reframed in this way, conflict between logics can be seen as a positive thing, as it provides fertile ground to develop new tools and techniques that will better account for social and cultural factors.

Different definitions of codesign. The first way the engineers dealt with conflicting logics was by fluidly defining codesign. Because codesign has not yet been fully codified, the engineers exercised some freedom with what it means to “do codesign.” Two definitions in particular emerged. The first focused on understanding while the second focused on ownership. Both attempt to improve social sustainability, but at times the two definitions appear to be at odds. *Codesign as Co-understanding* placed emphasis on "jointly discovering" (Simonsen and Robertson 2013:3) new and innovative solutions to a problem. It sought greater empathy between the engineers and locals by blurring the lines between the two groups. *Codesign as Co-ownership*, however, placed emphasis on ensuring that locals own the solution, but still maintaining boundaries between designer and user. This allowed the engineers to focus on mechanical aspects of the machine, channeling their collaborative efforts toward the broader system into which it would eventually be embedded. Table 1 below summarizes the comparison for easier reference.

[Table 1 about here]

Co-understanding:

The descriptions of codesign given in design literature commonly emphasize the *co-understanding* component of collaboration—that a disconnect exists between those with expertise of a problem and those with expertise in potential solutions, and that codesign creates an opportunity for groups with different strengths to jointly explore new solutions that fit the context of the problem. Ideally, this will increase cultural awareness and improve the social sustainability of products.

In the mandioca peeler project, engineers employed the *co-understanding* model of codesign to focus collaborative efforts on maximizing the machine's compatibility within the local context. This was the version of codesign that the group aspired to early in the project. For example, Peter’s effort to engage locals in prototyping and early design decisions reflect a *co-*

understanding model of codesign. In one design meeting, Peter and Dr. Marcus discussed the physical features that the machine would have, and Dr. Marcus emphasized the importance of a machine that feels intuitive, even familiar to the user. Too many steps or too many moving parts could be off-putting to a user. The group even considered the possibility of a “black-box” machine that is extremely advanced on the inside but dispenses familiar-looking mandioca peel scraps simply for the purpose of making the experience familiar to the user. The *co-understanding* model of codesign placed particular attention on designing a machine that was familiar, intuitive, and culturally-responsive, which it would accomplish by bringing collaborators into the center of the design process.

In the short term, the *co-understanding* model of codesign exacerbated tension between the engineering and codesign logics. Blurring lines between engineers and their collaborators prevented the engineers from approaching the machine as a purely mechanical challenge. They frequently had to incorporate social factors using tools and techniques designed for mechanical considerations. Furthermore, useful collaborator engagement can be difficult to obtain, especially when working internationally. Peter explained that conversations with Alberto and others had typically resulted in the collaborators deferring to his expertise.

On the other hand, a *co-understanding* model of codesign could help ease tensions later in the collaboration. When the time came for the engineers in this project to share their progress with local stakeholders, they found that locals lacked the understanding necessary to discuss the machine, because they hadn't been more involved in its development. Virtually all insights that collaborators offered on the test day were "unusable" by the engineers' estimation, since they lacked a basic understanding of the design process so far. Most of the ideas shared had already been considered by a team of engineers months earlier, and had been ruled out for specific reasons. Rather than explain this reasoning to stakeholders, the engineers found themselves nodding and smiling and saying, "We'll have to look into that."

Co-ownership:

Sometimes, the engineers defined codesign as a matter of *co-ownership.* They saw the machine as a mechanical project that needed to fit into a social system. Therefore, by collaboratively creating the broader system, the machine could be optimized on a mechanical basis and still fit seamlessly into the social context. Where *co-understanding* uses codesign to shape the machine, *co-ownership* partitions mechanical factors to the engineers and non-mechanical factors to local collaborators. The project can still be considered collaborative on the basis that two groups are working toward a common end: high-quality, efficient farinha production. Boundaries between the two groups, however, remain fairly distinct.

This approach to codesign had obvious benefits. When tensions arose due to conflicting logics, *codesign as co-ownership* allowed the different logics to occupy their own territory. For instance, it facilitated a designer-client dynamic that both the engineers and locals seemed more comfortable with. When including stakeholders in design decisions became untenable (often because of their mechanical nature), the collaborative aspirations of codesign were compromised in favor of this more traditional arrangement.

Although *codesign as co-understanding* eased tensions in the short-term, it seemed to exacerbate them later on. When involving stakeholders on test day, for example, it became clear that they lacked context needed to be full participants. Similarly, the need that the engineers felt to lower expectations prior to unveiling the machine likely stemmed from having not included them more fully early on. The implicit designer-client relationship that had eased tensions early on became explicit and had to be reconciled with the ideals of codesign.

One implication of this finding is that practitioners ought to thoughtfully determine the type of collaborative relationship they wish to establish. Each will have distinct strengths and weaknesses. For example, an undertaking like the mandioca peeler project may benefit from a *co-understanding* model during the conceptualization stage, with a focus on meaningful collaboration and rich, qualitative research. Later, when the project takes on a more technical focus, it may benefit from a *co-ownership* model, in which the engineers can focus on their work, trusting that their local counterparts share the broad vision of the project. On the other hand, projects with a less technical basis may find *codesign as co-understanding* a more productive model from inception to completion, as this model more fully captures the collaborative aspirations of codesign.

Codesign incarnate. Another way that the engineers eased tensions between traditional engineering and codesign was by outsourcing certain elements of codesign. When the demands of codesign clashed with the tools and practices of engineering, the engineers were forced to shift in and out of the engineering logic. They eased some of this burden by externalizing the demands of codesign to their schedule (for example through Skype calls and other interactions with collaborators) and to individuals in the group (me in particular). Externalized codesign demands in their schedule and on their team allowed the engineers to focus on their role as engineers, without losing a sense of accountability to the ideals of codesign.

This practice presents an interesting juxtaposition to previous work in neoinstitutional theory. Ethnographic research by Tim Hallett (2010) found that institutional myths can be embodied by individuals. In his study, the ideal of "accountability" held symbolically within the institution of education becomes tangible in the form of a newly-hired, school "CEO." The incarnation of the "accountability myth" leads to a tumultuous recoupling of practices and ideals.

Contrastingly, the engineers in the present study recognize that codesign ideals and engineering practices are not seamlessly unified. Rather than manage this tension internally, they externalize the "myth" of codesign to allow themselves room to "be engineers." To further demonstrate this point, it would be as if the teachers in Hallett's study were so committed to both their teaching practices and to the ideal of accountability that they voluntarily appointed a "CEO" to embody "accountability." Better to be teachers in tension with a CEO than to fill both roles simultaneously.

The idea of "codesign incarnate" can be demonstrated with two examples in which I was personally involved. For example, on the team's second trip to Brazil, the engineers wanted to include cultural and social factors in their assessment of the prototype machine's effectiveness, but mechanical concerns were so predominant that it became extremely difficult to focus any attention whatsoever on non-mechanical factors. The team outsourced social considerations to me, allowing them to "do engineering" while relying on me to raise important non-engineering questions. On multiple occasions, Dr. Marcus stated how my involvement had forced them to reflect on social factors that would traditionally be ignored. While assembling the machine, he expressed that if I weren't there they would be entirely focused on the "tightness of bolts" rather than the way the machine would affect the people that interact with it. Likewise, throughout the project, social impacts that were difficult to fit into the team's models would sometimes be set aside. I began raising questions about these factors, and worried that my concern might be unwelcome. Only later did I come to understand that this dynamic had allowed the engineers to "be engineers" while doing codesign.

As a "stake in the ground" to which the engineers were tethered, I was able to preserve an awareness of cultural factors in the project, liberating the engineers to more fully operate within an engineering logic. As demonstrated in the following section, the tension between the engineers and their various “stakes” (the written codesign plan was another) allowed them to stretch the logic of engineering toward a greater awareness of social impacts and cultural factors.

Stretching an institutional logic. Tension between logics undermined some elements of codesign. However, it provided opportunities to stretch the engineering logic and explore new tools and techniques for engineers to incorporate social impacts into their models. Engineers concerned with social and cultural factors are faced with the challenging task of using mechanical means to produce some impacts and avoid others. Perhaps this is why much of engineering has traditionally, as the subjects of this study articulated, ignored social impacts. The tools of traditional engineering are not particularly equipped to account for social factors. Detailed logic models help them understand and predict relationships of various inputs and outputs, but complexity is compounded astronomically when irrational human behavior is introduced. As social sustainability becomes increasingly salient, engineers are faced with the paradoxical task of using a mechanical framework to address decidedly non-mechanical social impacts. Codesign, with this paradox in mind, can be productively viewed as a frontier in the pursuit of a more socially sustainable and culturally responsive form of engineering. The group’s commitment to codesign (including, for example, inviting me to join the project, establishing a “codesign plan,” and regularly checking in with collaborators) provided them opportunities to stretch the logic of engineering in new directions—to account for what it had previously ignored.

The dissonance between mechanical and social thinking has been highlighted in numerous engineering projects of the recent past. In “The Struggle for Water”, for instance, Wendy Nelson Espeland documents the competing rationalities of three distinct groups: traditional engineers (which she terms the "Old Guard"), a more socially-conscious conglomeration of engineers and non-engineers (the "New Guard"), and indigenous locals who may bear the brunt of the project's potential negative consequences (the Yavapai). The New Guard—a conglomeration of different logics, like the mandioca peeler codesign group—appeals to a "neutral" and "universal" rationality of objectivism in a strategic move to reconcile the mechanical with the social. For Espeland, the New Guard's appeal to objective rationality is motivated by a desire to be "neutral." Espeland fails to note, however, that this objectivism is particularly compatible with the mechanical logic of the Old Guard (traditional engineers).

Like the New Guard, the social-impact-minded engineers in the mandioca peeler project appeal to a "neutral" rationality as a way to deal with complex questions of meaning and values. They use "objective measures" to translate social factors into actionable data *within the engineering logic.* For example, they attempt to objectively measure "time saved" by the machine, and to base decisions on these terms, so as to avoid numerous complex, value-ridden questions like "how time ought to be spent." This process, however, disguises the fact that it is still the *engineers* who value the ideals of quantified productivity, mechanical efficiency, and time saved. Both Espeland's New Guard and the mandioca peeler codesign group operate on the terms deemed legitimate by their own "Old Guard." For the codesign group in particular, the appeal to objective measures makes cultural factors intelligible to the training, tools, and techniques of traditional engineering.

The attempt to translate social and cultural factors into engineering terms illuminates new frontiers of engineering. It is a fraught but productive enterprise. In the present case, the team was often unable to account for crucial social factors because they could not be easily quantified. These were sometimes pushed into the background. However, when existing tools fell short of capturing the complexity of the social world, the codesign engineers identified areas of opportunity to develop new ones. I came to think of this process like increasing resolution on a TV. It may never fully capture reality, but increasingly approaches it. When I presented this idea to Dr. Marcus, he agreed. "When the first TV came out, people may have said that it was nothing like reality—all fuzzy and in black and white. But they had to start somewhere. And now, with HD and 4k and whatever comes next, you can hardly tell it's not real."

The group often interpreted their work by discussing previous advancements in design and engineering practices. For example, John once pointed out, designers of the past simply assumed they knew what people wanted. Design catastrophes like the Ford Etsyl led designers to question that assumption. Additionally, as Dr. Marcus described, organizations like IDEO have shown that "you can calculate everything and get back to me in two weeks with something that's probably wrong anyway, or I can talk to someone and try it out for an hour and know right away." Their own work was frequently contextualized using this trajectory of low-resolution social and cultural responsiveness (such as the Ford Etsyl) toward increasingly high-resolution responsiveness (like IDEO and its contemporaries).

The group recognized its inability to account for every relevant factor, but viewed the attempt as worthwhile. Even failure in some areas would be a success if it increased "resolution" by any degree. During the mandioca peeler's development, the engineers grappled with questions of whose values matter, how to address them mechanically, and which potentially negative impacts are worth fretting over, and clear answers were almost never available. As Dr. Marcus explained, however, "driving down the road has risks, but we still need to get somewhere." Later, relying on another metaphor, he added that development work is like throwing a stone into water. "Traditional engineers might only worry about the first ripple or two. We're trying to expand that, but even we have to draw the line somewhere—so we focus on ripples one through nine, for now." The mandioca peeler project and, in a broader sense, the engineering lab itself, exists at the point of tension between traditional engineering and a heightened awareness of engineering's shortcomings. They are, in the language of organizational theorists, *institutional entrepreneurs.* As Dr. Marcus explained, "We don't have enough confidence in the traditional approach to say that the traditional approach by itself is good enough. We're saying that the traditional approach has gotten us very far, and it's time for us to add some layers to that that will enhance what it can do. And one layer that needs to be added is the social impact layer." The attempt to build on the engineering tradition will necessarily lead the team to experience failure and frustration, and to face understandable skepticism from social scientists and others. But they expect that this tension and frustration will be the means to emergent tools and practices that advance their discipline.

Spread of Developmental Idealism

The codesign project attempted to account for a wide variety of stakeholder perspectives, an extremely challenging task that led to revelatory conversations and interesting new techniques. However, for a group that tries to rely as much as possible on objectivity, several important questions remained ambiguous. For example, it was never clear whose values to respond to when stakeholder perspectives conflicted. Additionally, the team came to recognize that the project had the potential to either exacerbate existing inequalities or to impose the team's own values of equality, democracy, and progress. Seldom was a neutral option available when discussing social impacts. This challenge sheds new light on some of the mechanisms by which developmental idealism (A. Thornton, Dorius, and Swindle 2015) is spread.

One of the greatest challenges involved in attempting codesign was knowing whose values to respond to. When an objectively "best" solution was not self-evident, the group attempted to define what was “best” on local terms. However, even different locals define this differently, and no clear path forward emerged, and in the attempt to objectively weigh some priorities against others, the perspectives of some stakeholders are inherently favored over others. For example, the group’s goal was to maximize positive social impacts while minimizing negative ones. However, doing so, at least from an engineering perspective, requires measurable indicators of what is “positive” and what is “negative.” Despite including a broad range of social impacts and extremely diverse respondents in their research, those with the most easily-quantified priorities (such as cost-effectiveness, quantified productivity, or wealth creation) often gained centrality. In the language of institutional logics, these tended to be stakeholders with a modernizing logic.

At times, the group recognized their inclination toward stakeholders with a modernizing logic and considered ways to counteract it. For example, they recognized that the new technology could drastically alter the way many farmers spend their days. Typically, families sit together and peel *mandioca* by hand for hours—even days—at a time. Concerned that a mechanized peeler would decrease family time, the group considered ways to remedy this negative impact. However, further discussion with local stakeholders made clear that the team’s concern was guided by assumptions about family time that weren’t necessarily true—that peeling *mandioca* by hand as a family was a bonding experience that shouldn’t be lost.

With echoes of utilitarianism, the engineers sought to provide the greatest good for the largest number of people. Doing so meant measuring different stakeholder priorities and assigning them weights that would allow for objective comparison. However, the group soon found that the *desirability* of social impacts could not be objectively measured—it depended on the values of the locals who would experience them. Thus the group found itself riddled with questions such as, “Should the machine’s operation require multiple people (more jobs) or be almost entirely automated (greater return on investment)?” Similarly, they wondered, “Do we create one large machine (greatest benefit for the cost) or many small machines (a smaller good for a larger number of people)?” When stakeholder preferences differed, the group wondered, as Peter put it, “Whose values do you value?”

This predicament reflects one of the ways in which, as developmental idealism theory warns, the rest of the world is being actively remade in the image of the US and Northwestern Europe. Even the conscious decision to “empower locals” can fall short if actors fail to account for the multitude of different stakeholder perspectives, and the many subtle ways in which some stakeholders may be served at the expense of others. Codesign, perhaps more than other methods, attempts to respond to these concerns, but it still falls short.

Fortunately, each of the local stakeholders interviewed for this ethnography, including indigenous and rural farmers that were far removed from the project, wanted this technological intervention in some form. While some hoped it would improve job prospects and increase productivity, others hoped it would lighten the workload and make farmlife more appealing to the younger generation (this will be further explored in the next section). In some form, virtually everyone viewed it as a positive prospect. But the specifics of the machine remain to be shaped, and they will likely be shaped by the forces that most resonate with the engineers’ own logic—those with a modernizing logic. Therefore, despite attempting to design this technology on local terms, the intervention may still perpetuate elements of developmental idealism, infusing the project with values of free market, agricultural productivity, and economic expansion.

As recognized by the engineering team in this study, development projects are not neutral. They empower some groups over others, and they respond to certain values at the expense of competing ones. It is not obvious how engineers are to deal with such concerns. They may appeal to objectivity and quantitative measures, but must recognize that doing so necessarily places value on those things which can be quantitatively measured. Alternatively, they may attempt to carry out their work in such a way as to remedy certain social inequities, but should recognize the tendency to impose modern, Western ideals onto other cultures.

Marginalized Groups

The engineers must respond to the values of some stakeholders over others, or else impose their own values on the project. In the past, as Dr. Marcus explained, engineers would have responded to the priorities of whomever was paying. Recognizing the shortcomings of such a model, however, the group attempted to use more collaborative methods to gather data from vastly different stakeholders. Broadly speaking, their data included the myths of the indigenous, the lifestyle patterns of rural farmers, the entrepreneurial aspirations of the cooperative, the scientific findings of EMBRAPA, and much more. When these data entered the group's field of vision, though, some elements were much easier to incorporate than others. EMBRAPA and the farming cooperative, with their modernizing logic, hold values that are fairly translatable to the engineering logic—cost-effectiveness, quantified productivity, and wealth creation, to name a few. The values of many rural farmers and indigenous people, on the other hand, are much more difficult to incorporate into models of engineering. How the myth of Mani, for example, might affect the machine's design was never entirely clear. A contemporary example from the United States may help illustrate why this is the case.

Espeland's research in "The Struggle for Water" is not alone in highlighting the challenge of indigenous voices to be heard by modernizing forces. Take, for example, the struggle between different interest groups with regards to the Dakota Access Pipeline. If power structures rely primarily on quantitative models, then the priorities of business and political stakeholders (ie. ROI, resource availability, votes) may be much more readily considered than the priorities of indigenous peoples. It is not obvious, for example, how an engineer might quantify the sacredness of indigenous sites or the connectedness of people to their land, just as it was not obvious how the mandioca peeler design team could account for the mandioca myth.

One of the greatest concerns that the mandioca peeler design team had at the outset of the project was to minimize the likelihood of negative social impacts from the machine. For example, while some of the social impact categories focus primarily on the potential for positive change—for example by increasing opportunities related to *education*, *paid work*, or *health and safety*—other social impact categories helped focus the group's attention on avoiding negative social impacts. The categories of *social inequality* and *gender*, for instance, compelled the group to consider the possibility that new technologies could exacerbate inequities between groups in the communities where they work. Likewise, the category of *cultural identity* brought up many important considerations, including the mandioca myth discussed earlier in this paper. However, as established in the previous paragraphs, these considerations were extremely difficult to interpret within an engineering framework, making it nearly impossible to incorporate them into decision-making models. Unable to account for all perspectives, the engineers often had to settle for a more limited scope. Unfortunately, many traditional perspectives and unquantifiable social impacts may escape their purview.

The complexity of these risks is evident in several key decisions the engineers were forced to make. For example, one of our rural contacts fully supported the project, despite having very little interest in modernization or measurable increases in productivity. Content to farm casually and even haphazardly, this farmer still believed the machine to be a necessary change merely because it would alleviate the onerous task of peeling by hand. And yet, as Peter noted, it was entirely likely that the machine could price this farmer out of the market. The man did not view the machine as a threat to his traditional lifestyle, and yet the group knew that adopters of the new technology would have a dramatic advantage in terms of speed, quality, ease of use, and price. Our friend could choose to preserve his traditional methods, but doing so would likely decrease his economic position substantially.

An alternate perspective. While the implications of such marginalization are serious and worth considering thoughtfully, they fail to tell the whole story. Groups in Brazil had diverse reasons for supporting the new technology, and indeed some of these likely fail to account for certain risks. But the mandioca peeler team became increasingly aware, late in the course of the project, that marginalized groups were not passive victims of modernization's ceaseless advance, but rather active participants in shaping their world. One rural farmer described the machine as a way to make traditional life more appealing to her grandchildren. She and others expressed concern that a large portion of the younger generation has moved to the city (Manaus) in search of jobs, that agricultural life is too gruelling and pays too little to be sustainable. Similarly, the Mura expressed desires to modernize certain elements of their lives not *in spite of* traditions, but *as a vehicle for* those traditions. As the chief said, "Mandioca will continue the same way…it will be planted in the same season, it will be harvested in the same season. Nothing will change." This view appears to reflect a "hybridization" model of globalization that deserves further study.

Admittedly, the simplistic view with which I approached many important questions—destroying culture versus preserving it, magnifying gender roles versus creating new possibilities, increasing inequality versus alleviating it—failed to reflect the rich nuance with which locals view their context. As active participants in their own future, these individuals select some elements to incorporate and others to reject, just as the Mura do with their jungle surroundings. The challenge for engineers, designers, and others is to be aware of their own influence without discounting the agency of local actors. Outside forces must be mindful of power dynamics and the possibility of negative impacts, but if we take seriously the notion of collaborative design, we must recognize our limited ability to calculate impacts—positive or negative—and view locals as autonomous agents. Despite its many shortcomings, this is something codesign has the potential to facilitate.

This study demonstrates some of the ways in which development projects may further marginalize disadvantaged groups. Institutional logics play a noteworthy (and underappreciated) role in this marginalization. However, much of development and marginalization literature fails to recognize the role that individual actors have in the modernization of their local contexts. Globalization is not inherently something that happens *to* developing communities, but can be something they take an active role in shaping. Codesign may help facilitate this collaborative form of development.

CONCLUSIONS AND LIMITATIONS

The purpose of this ethnography has been to shed light on the latest frontiers of international design and to further our understanding of institutional logics. The influence of institutions on actors is often easiest to see in the points of conflict multiple logics. Furthermore, looking at instances of logics in conflict can reveal the innovative ways in which individual actors inhabit, navigate and transform the institutions around them (Hallett 2010; Hallett and Ventresca 2006). To that effect, this study makes two contributions to our understanding of how practitioners deal with conflicting logics.

First, the engineers in this study attempted to overlay their engineering logic with a codesign one in order to explore new possibilities. Though they didn't use the language of institutional theory, these engineers consciously adopted many of the symbols, ceremonies and demands of a "codesign logic" specifically for the purpose of stretching their own engineering logic in that direction. Much of current institutional logics literature depicts individuals as unconsciously shaped by institutions but fails to highlight the ways in which actors consciously navigate and even harness distinct logics. This research remedies that shortcoming by showing how the engineers strategically incorporated elements of a competing logic to stretch their own.

Second, when simultaneously embodying both the codesign and engineering logics became untenable, the engineers outsourced some elements of the codesign logic. These served as stakes in the ground against which the engineers could strain from within the engineering logic, helping them explore new tools and techniques. Again, literature shows how institutions constrain individuals but largely ignores the power of the individual in shaping that relationship. This research shows that individuals can actually alter the form that institutional constraint takes by internalizing some elements and externalizing others. Far from being mere victims of tension between logics, the engineers in this study strategically adapted to make that tension productive.

I have connected codesign to illuminating literature from organizational theorists, development scholars, and sociologists with the hope that doing so will direct practitioners toward useful (but perhaps elusive) scholarship from the social sciences. Therefore, I believe this research provides several practical insights in addition to its contributions to literature. These will help future codesign efforts to better address the needs and wants of disparate stakeholders, many of whom hold values that are difficult to incorporate with existing practices. Two suggestions seem particularly informative.

First, the ideals of codesign seem best served by a *co-understanding* approach to collaboration. However, due to the technical nature of engineering, I propose that this approach be taken primarily during the exploration and conceptualization stages to establish a foundation of shared understanding and cultural sensitivity. Then, a *co-ownership* model may be used when the project takes a more specialized, technical turn, such as in the prototyping stage. In either model, successful codesign will greatly depend on frequent communication and a level of collaboration that may, for some time, remain at odds with the engineering logic.

Second, as the ability of engineers to model the social world improves, the increased "resolution" of their models may better equip them to address social impacts. However, it is necessary to recognize that even the highest-resolution virtual reality is not reality. Despite the revolutionary innovations we have seen and will yet see, quantitative tools will never fully capture human reality—the decades of lived experience of individuals nor the immeasurable inheritance of their forbears. Some spark of culture, history, and identity, it seems, will always elude those who wish to measure them. As demonstrated by the meaningful but unquantifiable experience of making farinha and walking with indigenous people, qualitative field research is able to capture much of what quantitative models ignore, but it is yet unclear what place such data has in the world of engineering. Currently, ethnography is used to inform the work of many engineers, but its role could be greatly enlarged to the benefit of many projects. International design projects built on a foundation of rich, cultural understanding would be much better equipped to understand and address social impacts. For example, engineering teams could dispatch engineering ethnographers, at the outset of a new project, whose sole purpose is to gain a deeper understand of the local context. The remaining challenge, however, would be inventing new tools and practices that allow for this level of messy subjectivity. Qualitative research, it seems, requires a comfort with ambiguity not yet abounding in the field of engineering.

This study examines only one project undertaken by one team of engineers in one location. The generalizability of exploratory research is admittedly limited, but a case study such as this serves to identify new areas of interest and to provide a foundation for further scholarship. Furthermore, the study has benefited from a broad, interdisciplinary focus, which likewise comes with tradeoffs. Each body of scholarship necessarily has its own precise language, specialized areas of focus, and internal debates, and yet such specialization can limit our ability to draw illuminating connections between the distinct disciplines. These finer points of clarity ought to be explored in future research. At the expense of some nuance, much can be learned by bringing disparate fields of study into dialogue with one another.

The great promise of codesign is that it brings a greater diversity of voices into the rooms where decisions are made. A greater awareness of distinct institutional logics will help practitioners navigate points of logical tension, identify perspectives have been excluded altogether, and question the assumptions that often accompany development projects. For engineers in particular, it will illuminate the visceral, though perhaps not inevitable, tension between the traditional engineering and a more socially sustainable future.

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Table 1. Comparison of Codesign Definitions

Codesign as Co-understanding	Codesign as Co-ownership
Blurred roles.	*Defined roles.*
Emphasis on participation.	*Emphasis on accountability.*
Exacerbates tensions early but may ease them later.	*Eases tensions early but exacerbates them later.*
Focuses attention on social/cultural factors of the machine (e.g. usability, sustainability, cultural fit).	*Focuses attention on social/cultural of the broader system (e.g. workflow, access, job creation).*