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Making when ends don't meet: Articulation work and visibility of domestic labor during grassroots innovation.

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Making when Ends don't Meet: Articulation and Visibility of Domestic Labor during Grassroots

DIY Innovation

Abstract

Makerspaces, hackathons, and technology incubators are key emerging sites for technical communication practice and research. Yet, little is known about how resource-constrained, non-Western families practice DIY (*Do It Yourself*). Revisiting craft's roots in families practicing artisanal trades, I find that the visibility of DIY innovation relies on the infrastructuring of family members who perform articulation work despite tremendous economic risk through traditional and transgressive family and gender roles and identities.

Keywords

DIY; innovation; repair; making; family; gender; postcolonial; Global South

Introduction

Family is of longstanding theoretical and methodological interest to craft scholarship and research on paid and unpaid participation in technology design, repair and maintenance, and (re)use. Homes are important as sites situating historical, social, material, and cultural practices of technology design and use (Ammari, Schoenebeck, & Lindtner, 2017a; Bell, Blythe, & Sengers, 2005; Gelber, 2013; Silverstone & Haddon, 1996; S. Wyche, Sengers, & Grinter, 2006).

Studies of domestic technology appropriation (Bell et al., 2005; Silverstone & Haddon, 1996) recognized users' agency in novel adaptations of household artifacts for material needs, and, social roles and identities (Ammari, Schoenebeck, & Lindtner, 2017b; Gelber, 2013; Daniela K. Rosner & Fox, 2016; Vines, Clarke, Wright, McCarthy, & Olivier, 2013; Wallace et al., 2013). Participative inquiries into assistive technologies for vulnerable home users have generated novel empathic designs for care-provision (Lindsay et al., 2012; Wallace et al., 2013). The salience of domestic and collective DIY participation for normative and transgressive enactment of Western(ized) family roles and identities has also been well established (Ammari & Schoenebeck, 2016; Ammari et al., 2017b; Balaam et al., 2013; Rosner & Fox, 2016).

Lacking in this literature are similar accounts of making as a contextualized practice that is mutually constituted with enactments of non-Western family identities and roles. Researchers acknowledge the importance of kinship ties for facilitating non-Western actors': (a) participation as users in community rituals, forums, and events (Winschiers-Theophilus & Bidwell, 2013) and, (b) socialization into repair professions (Ahmed, Jackson, & Rifat, 2015). Yet, little is known about how non-Western families with limited economic resources experience and enable participation during DIY-based innovation in the absence of external intervention.

Extending technical communication research that has called for attention to non-Western sites (e.g., Agboka, 2013; Ding, 2013; Walton, 2013) the current study sought to explore answers to the following question: *How do non-Western family members participate in DIY innovation?*

I report on contingent and long-term DIY participation experienced by families of eight *grassroots innovators*¹, *individuals with limited formal education (grade 1-12) that designed novel agricultural, mechanical, and electrical occupational and domestic technologies without initial formal institutional support.*

Drawing on multisited, participant observation of domestic and occupational routines, and, interviews (N = 74) with innovators, their immediate and extended family members, peers, neighbors, local and institutional collaborators, and users, and, archival research, I provide accounts of non-Western DIY as experiential practices situated in local historical and occupational contexts.

Such situated narratives problematize narrations of DIY's origins as an activity associated with Western(ized) homes (e.g., Gelber, 1997), self-help groups (e.g., Oudshoorn & Pinch, 2003), hacking collectives (e.g., Lindtner, Bardzell, & Bardzell, 2016), and sustainability movements (e.g., Philip, Irani, & Dourish, 2012).

Research on DIY-based innovation in non-Western sites has focused on participation, reflexivities, experiences associated with appropriating technologies and cultural narratives across varying levels of privilege (Ahmed et al., 2015; Jackson, Ahmed, & Rifat, 2014; Sun, Lindtner, Ding, Lu, & Gu, 2015; S. Wyche, 2015). I theorize low income non-Western families rather than returning diaspora, local elite (e.g., Avle & Lindtner, 2016; Irani, 2015; Lindtner, Hertz, & Dourish, 2014), and, Western(ized) researchers-designers (e.g., Lindtner et al., 2016; Taylor, 2011).

¹ All of the DIY makers I learned from were scouted and supported by Honey Bee Network organizations, in particular, the National Innovation Foundation. Therefore, I use the NIF's definition for the term grassroots innovators. Given the centrality of DIY practices to the grassroots innovations I studied, I also use the term grassroots innovator/innovation and DIY maker/making interchangeably.

I interrogate emphatic claims in long-term, transformative legacy-seeking narratives of DIY innovation as sustainable, frugal, empathetic, prosocial, open technology and social movement driven by necessity, pleasure-seeking, or civic/environmental motivations. I explain the concrete, and contingent processes by which DIY occurs with varying, often contradictory social and economic outcomes for non-Western families.

I demonstrate how distinct and apparently incommensurate subsistence (e.g., Ahmed et al., 2015; Jackson et al., 2014; Wyche, Dillahunt, Simiyu, & Alaka, 2015), prosocial (e.g., Fuchsberger et al., 2016; Hackney, 2013), hobbyist (e.g., Gelber, 2013; Rosner & Fox, 2016), and entrepreneurial (e.g., Lindtner et al., 2016) motivations for DIY are manifest and coalesce as makers are socialized into and out of family occupations via participation in repair professions, paid employment, and, entrepreneurial ventures.

Integrating researchers' focus on the visible enactment of gender roles and family identities via DIY practices (e.g., Ammari et al., 2017b; Balaam et al., 2013; Gelber, 1997; Rosner & Fox, 2016; Star & Strauss, 1999; Wajcman, 2010) and the visibility of articulation work (Star & Strauss, 1999; Wajcman, 2010), I examine how innovators and family members performed articulation work via traditional *and* transgressive gender, occupational, and social roles, to accomplish cooperative tasks in direct and indirect support of grassroots innovation.

Articulation work is made visible when family members provide concurrent, divergent framings of articulation work as assistance and empathic cooperation. DIY makers gain positive visibility and reputation in their local and occupational communities, when families talk about articulation work in symmetric terms as an act of empathy and solidarity rather than asymmetric, utilitarian terms as assistance or aid. Extant asymmetries with members of the immediate and extended family makers' access to scarce capital and adjudicate the social and economic appropriateness of DIY practice

throughout the maker's lifetime. Family members' influence on makers persists regardless of reputational and material gains/losses or institutional intervention.

In the following sections, I first review historical studies of craft as a household profession, literature on family and DIY, noting its emphasis on technology appropriation by households in WEIRD (western, English-speaking, industrial, rich, democratic) domestic contexts.

Second, I note prevailing characterizations of non-Western families as users contradict their acknowledged role facilitating entry and training in repair professions. Lack of research on family members' participation in non-Western DIY innovation and repair is a key gap given the centrality of family and home as sites where DIY participation enables enactment of family roles and identities, and DIY practices are nurtured through articulation and cooperation.

Third, I report on the current study's research design, describing the rationale for sampling, data collection and analysis. Fourth, I report findings, specifically, the influence of makers' socialization into family occupations (or, lack thereof) on their choice of innovations targeting and resources drawn from specific occupational communities. Finally, I draw broader implications of studying DIY making as a domestic activity that renders non-Western homes legible as spaces for everyday encounters wherein innovators experiment and enact heterogeneous practices of making, repair, and innovation.

Researchers view family primarily as a source of holistic requirements and testing data. Family members participate to varying degrees as users, informants, and co-designers on expert-led projects. Investigations of domestic technology use challenged the design-use dichotomy by highlighting the consequential ways in which home users appropriate, resist, and avoid technology.

Family members as users

Studies of domestic technology use demonstrate its non-technical implications. Western homes have been studied as sites where family members domesticate new technologies for practical/instrumental and symbolic/identity work (Silverstone & Haddon, 1996). Post-war industrialization of consumer goods production led homes to emerge as sites where microwaves, washing machines, and vacuum cleaners were consumed and domesticated through context-specific identity work and routine use by household members (Gelber, 2013; Oudshoorn & Pinch, 2003). Asymmetrical, gendered use and design of domestic technologies yielded task efficiency without reducing the disproportionate female share of task responsibilities at home (Gelber, 2013; Wajcman, 2010).

Critiques of domestication's use-centered perspective (Kline, 2003; Wyatt, Oudshoorn, & Pinch, 2003) argue for attention to variation in motivations, contexts and practices of resistance and non-use of technology. The current study extends extant interest in technology non-use by examining family members' cooperation and resistance toward making rather than use.

Non-WEIRD families as users

Family members in non-Western settings are typically studied as end users of ICTs. Similar to the broader literature's framing of family as source of user data, non-Western families are viewed as resourceful media users interested in diverse issues including DIY, health (Peyton, Poole, Reddy, Kraschnewski, & Chuang, 2014), entertainment (Liu et al., 2010), information security (Oduor, Neustaedter, & Hennessy, 2016), identity work (Awori, Vetere, & Smith, 2015; Oduor et al., 2016), and, relational maintenance (Wyche & Chetty, 2013).

Oduor et al. (2014, 2016) describe how Kenyan families reproduce and transform normative gender and family roles through independent, intermediated, and shared use of ICTs to maintain economic (e.g., remittances, currency exchange information) and social (e.g., communication with family as diaspora)

relations across geographical boundaries. They suggest that urban families are more likely than their rural counterparts to enjoy prior and stable access to the knowledge, experiences, and infrastructures necessary for using advanced technologies. Wyche, Simiyu, and Othieno (S. Wyche, Simiyu, & Othieno, 2016) highlight tensions between rural Kenyan women's non-revenue generating mobile phone use for family communication and mobile phone operator Safaricom's profit-motive.

Awori, Vetere, & Smith (2015) discuss how Kenyan diaspora use ICTs for intergenerational family communication, and, maintain and perform their ethnic identities. Diaspora users worked around the lack of detailed information online on indigenous practices, and difficulties in using text- and visual-based tools to communicate the bodily literacies associated with traditional knowledge and ritual (Awori, Vetere, & Smith, 2016).

Family members as co-designers

Scholarship has sought to reconfigure family members' design participation as co-designing users of functional, affective and analogical artifacts targeting physical, cognitive, and emotional health and well-being (Wallace et al., 2013). This work emphasizes the importance of empathic approaches in recognizing and enabling member agency as users and co-designers. Extending the family as co-designer perspective to non-WEIRD sites, I study whether and how family members enact empathy as co-designers of grassroots innovations.

Non-WEIRD families as co-designers

Similar to participatory approaches that involve families as co-designers (McCarthy & Wright, 2015; Vines et al., 2013), research construing non-Western community members as co-designers acknowledges researcher-designers' moral responsibility to participate with respect and humility for local knowledge practices based on multimodal literacies, kinship relations, and communal traditions. This body of work has developed innovative research designs, e.g., (N. Bidwell & Hardy, 2009; N. J.

Bidwell et al., 2013; Winschiers-Theophilus, Chivuno-Kuria, Kapuire, Bidwell, & Blake, 2010) aiming to decenter the designer rather than strive to be user-centered as advocated by conventional participatory design paradigm.

Studying family participation in making as co-designers problematizes the categorization of craft into component aspects such as political and material (Roedl, Bardzell, & Bardzell, 2015). Responding to calls (Buechley & Perner-Wilson, 2012; Mellis, Buechley, Resnick, & Hartmann, 2016) for studies that integrate material and sociopolitical aspects of DIY craft, I study family and home as sites where sociopolitical, economic, and local cultural issues coalesce and impinge on craft practice. In doing so, I problematize the claim that hobby is a special case of bricolage or making-do (Buechley & Perner-Wilson, 2012) by highlighting the centrality of family members' articulation work to hobbyist making.

Family members as makers

Western hobbyist DIY making from the turn of the 20th century has been studied as depoliticized, class agnostic, gendered, playful, “pleasurable labor” performed by amateur enthusiasts *appropriating* technologies at home (Bell et al., 2005; Gelber, 1997; Silverstone & Haddon, 1996; Wajcman, 2010). Household repair was pleasurable *and* more productive use of time than leisure activities (Gelber, 2013). Working on projects around the house became a way for upper class men to recreate their masculinity away from “effete white collar work” (Gelber, 1997), p. 75) doing domestic work.

Men rich and poor worked with their hands, allowing DIY to be framed as a masculine leisure activity rather than necessity-driven hacking to save money. Engaging in pleasurable work that was not competitive like sport or paid labor justified gendered, asymmetrical assignment of DIY roles between females responsible for organizing tasks and heroic male problem solvers. American males designed and used space inside and outside the house for enacting such domestic masculinity in basement man caves and garage workshops (Gelber, 2013; D. K. Rosner, 2014).

Contemporary research on family in the context of craft, DIY, and making studies the enactment of family roles as social identities. For instance, parental roles serve as the basis of membership of some North American online and offline hacking/craft collectives (Ammari & Schoenebeck, 2015, 2016; Ammari et al., 2017b; Lukoff, Moser, & Schoenebeck, n.d.).

Western(ized) participants of hacking collectives enact upper and middle class parental identities online by appropriating social media tools to document the experience of parenthood, share information on parenting, and exchange support with other parents (Peyton, Poole, Reddy, Kraschnewski, & Chuang, 2014). Participation in gender-based hacking collectives enables members to transcend (Ammari et al., 2017b) and legitimize (Fox, Ulgado, & Rosner, 2015) normative, gendered stereotypes of domestic labor, as valued identity work.

Non-WEIRD families as repairers and makers

A parallel line of work has made a powerful case for studying non-western, informal DIY-based repair as a force for innovation and social and economic change (Lindtner et al., 2014; Wanyiri, 2015; S. Wyche et al., 2015). Repair scholarship documents the agency of those otherwise defined as users, (Ahmed et al., 2015; Houston et al., 2016; Jackson et al., 2014; Jackson & Kang, 2014) to carry out DIY practices in non-Western settings.

Repair research acknowledges the role of kinship ties in influencing movement into repair professions. For example, clan relationship networks socialize newcomers to mobile phone repair into apprenticeship roles (Ahmed et al., 2015; Jackson et al., 2014). Coordination of cooperative roles (Star & Strauss, 1999) during making by family members remains to be understood in more detail. The current study provides insights on this aspect by examining how family members socialize and support makers into DIY activities and related professions.

Repair scholarship in non-Western contexts has focused reuse and recycling of information technologies (IT) as e-waste (Burrell, 2012), repair of mobile phones (Jackson & Kang, 2014; S. Wyche et al., 2015) or, maintenance of computing technologies provided as aid to developing countries (Daniela K. Rosner & Ames, 2014) (cf., (Atalay, 2015; Graham & Thrift, 2007; Daniela K. Rosner, 2012; Daniela K. Rosner & Fox, 2016)). Following recent calls (Houston et al., 2016) to include new sites and actors in repair scholarship, I study repair as a skill learned during participation in family occupations and honed via design of electrical and mechanical technologies for domestic and occupational applications.

Extending work studying the enactment of gender as social identity in online and offline collectives by privileged Western(ized) actors, I examine DIY innovation in less privileged non-Western homes. In contrast to the dominant tendency to view human-technology interactions in both non-Western (Lindtner, Anderson, & Dourish, 2012) and domestic (Mackay & Gillespie, 1992; Silverstone, 1991; Silverstone & Haddon, 1996) sites as acts of *appropriation*, I justify studying how family members perform articulation work in service of cooperative tasks (Star & Strauss, 1999) necessary for DIY.

Articulation work involves managing the consequences of task distribution (Star & Strauss, 1999) in real time (Star, 1995). Articulation research has documented the invisibility of articulation work rendered primarily by females enacting gender norms in the form of underpaid or unpaid domestic services at the workplace (e.g., Bendifallah, 1987; Pekkola, 2003; Schmidt & Bannon, 1992; Strauss, 1985), and, care provision by professionals (e.g., Bossen, Christensen, Grönvall, & Vestergaard, 2013; Bowker, Timmermans, & Star, 1996; Christensen & Grönvall, 2011; Kirk, Chatting, Yurman, & Bichard, 2016) and family members (Timmermans & Freidin, 2007). Here, I extend studies of domestic articulation work by investigating routine, unpleasurable chores and errands (Star & Strauss, 1999; Timmermans & Freidin, 2007) performed by families during DIY innovation. Non-western families practice transgressive and traditional gender-based domestic articulation work, enacting *negotiated endurance*

(Rosner & Ames, 2014) of resource constraints and tensions between makers' hobbyist motivations and their families' emotional, social, and material aspirations and needs.

Methods

I undertook participant observation of eight serial innovators, individuals who have a sustained, public record of developing multiple technological innovations across seven rural, semi-urban and urban sites, located in the western Indian state of Gujarat. Innovators who had developed innovations for the same application areas were selected, ensuring relative homogeneity within-strata of application areas. Working in Gujarat, I could deepen insights examining variation in contexts in a single state, study sites associated with DIY for varying durations, save time to travel between sites, and increase my proximity to institutional stakeholders.

Data collection in the field consisted of daily observations of innovators' routine activities. These observations were conducted primarily as "go-along" interviews with key informants including innovators, their collaborators, family, friends, and innovation users about their experiences, routines, and practices related to innovation at the grassroots (Kusenbach, 2003). Participant observation and go-alongs lasted between six to ten hours per day with approximately two to four hours being captured on video, and the rest through a combination of audio recording and note taking.

In addition to participant observation, I interviewed innovators' family members, peers and collaborators of innovators, within and outside the local community (N = 64). The corpus of usable data analyzed for the present study included 46 hours of recorded audio and video, 210 pages of handwritten field notes, 212 single-spaced pages of interview transcripts, and over 600 pages of archival documents including innovator profiles, innovation summaries, laboratory test reports, market research, and correspondence.

I conducted member checks, returning to each site for two to three days to discuss preliminary findings with informants and confirm my observations about place and space (Dourish, 2006). Analysis of the

data collected using the methods described above began by treating each innovator as a separate case (Yin, 2009). I integrated archival and ethnographic data to construct a running narrative describing each innovator's practices and experiences developing grassroots innovations. This process was repeated for each of the eight innovators observed during the course of data collection, yielding detailed case histories, somewhat similar to the technology biographies used in HCI scholarship (Blythe & Monk, 2002; S. Wyche et al., 2006).

Coding of case histories was non-exclusive and carried out with the objective of generating a word or a short phrase that described the sequence in which routine actions, speech, or events occurred. Following a dialogic approach (McCarthy & Wright, 2015) these words and phrases (or codes) were action-oriented. The case histories produced were subjected to within-case and cross-case analyses (Leonardi & Barley, 2008) during which related codes were aggregated into analytic themes. Cross-case analysis of analytic themes enabled theoretical replication (Van de Ven, Angle, & Poole, 2000; Yin, 2009) across cases involving similar technologies achieving different levels of innovation maturity.

Findings

Articulation work during DIY innovation

Family members perform articulation work necessary for DIY innovation by assuming concurrent roles that directly and indirectly enable DIY innovation. Articulation work includes visible enactments of logistical responsibilities, technical expertise, and verbal encouragement, and, less visible articulation work freeing innovators' time by performing paid and unpaid labor to support the family.

Visible articulation work

Material support to the innovation process may be provided in the form of financial and technical support. Amrutbhai has seen his son Bharatbhai continue his work in the fabrication of innovative agricultural implements.

In addition to training his son in the art of mixing, molding and firing clay, Mansukhbhai's father Raghavji helped design and build kilns for his products, and supervised workers during the mixing and casting of clay. During our conversations, Mansukhbhai would continually describe the different roles played by his parents and family members while he focused on researching the innovation:

My mother and father managed my business. I made fridges. When I sat down to make the fridge, I would give instructions to make the clay thus, do more mixing or grinding, and my mother would take care of the work. More than me she was an innovator... She was 70 and even then she never sat down. For me she was my hand. My parents are my two hands. Any cleaning, mitti mixing, more than me she worked to help me.

My father is at the kiln in the day, and also does the job of the watchman. He has never slept at home. My mother, my wife, and my son we all sleep at home. But not my father. Day and night, he is here. 24 hours. Just for eating and bathing he goes home. He has spent day and night helping me.

Since my mother passed away, my son sleeps at the factory, when the kiln runs (is being fired), he sits here and takes care of the factory.

Family members free up Mansukhbhai's time by assuming different roles related to daily responsibilities, allowing him to spend time designing innovations. Mansukhbhai describes thinking on the problem he is designing for in a constant, always-on (*satat*) fashion which includes time spent around family members: "The work we do, like I said before, the thought should not get out of our mind. Constantly ... *satat*. [When] walking, eating, sitting, doing *puja* (worship), just continue thinking about it." He describes acting like a man possessed when working on the refrigerator design:

At first I did not know anything -- just sat down like a pagal. Not like a man. I will ask for tea, my wife will bring. But the tea is left cold. Don't want to eat. That is pagal. I could not see anything but the fridge. I have focused completely on my work.

That Mansukhbhai is able to work on his ideas in the presence of his family members is a testament to their patience and acceptance of his work habits as much as his ability to concentrate on the problem at hand. However, this performance of *satat* (continual) thinking around family members is made possible in daily practice through the substitution of Mansukhbhai's family members across roles that are directly and indirectly relevant to innovation.

Mansukhbhai's son who is studying to be a ceramic engineer, is currently in charge of measuring production, setting production targets, and supervising the production of pots and the firing of the kiln. When he is away at college Raghavji takes over these responsibilities. The role of supervising daily production is thus shared between Raghavji and Ravi.

Mansukhbhai's father Raghavji sets the rate for wood, sourced from 150 km away in Gandhidham, for fires in tava kilns and sells wood to locals. He continues to throw pots on his wheel, distributes tasks and

wages to workers, and supervises workers to ensure they have sufficient and appropriate materials (e.g., clay stocks and working equipment), and remains responsible for the tava production line.

(In)visible articulation work

Visible material articulation work may be contrasted from less visible articulation work required to sustain the family budget in the absence of steady income from the adult male of working age. Raghavji continued to work as a mason to support the family when Mansukhbhai was struggling to establish his business. He even allowed the house he had built to be sold so Mansukhbhai could repay his debts.

Bachubhai's wife Jayaben worked in the fields so he could spend time in his *karyashala* (workshop). Over three years, Bachubhai learned farming under his father, but electronics and mechanical fabrication remained a stronger calling. While he would find unique ways to combine local needs with hobbyist interests in electronics and mechanical fabrication, it was Jayaben who took on the daily responsibilities of ploughing and watering the fields. She recounts working in the field to the instruction of her father-in-law:

I would be bent over in the field doing nindaman (removing weeds) while he (her father-in-law) would speak instructions. Bachubhai would be busy tinkering in the workshop. I could not even look at my father-in-law to see where he was pointing toward or what he was describing. This is how I learned to work the land.

As a daughter-in-law Jayaben had to adhere to *ghoonghat* (veil) – the practice of covering one's head and face when around adult males, making it difficult to communicate with her father-in-law in the fields.

Jayaben remembers that Bachubhai would rarely visit the farm and preferred to spend time working in his *karyashala* (workshop). She is only speaking in half-jest when she tells Bachubhai that he does not know farming, and is only able to work on the farm under her guidance. A wry Jayaben gently rebukes

Bachubhai for wasting money on tinkering while making her perform tasks that were part of his traditional responsibility as the son toward his father's land:

“temne khub paisa khoto kariya...hu khetar ma jaine kaam karati hati ane te ghar ma betha betha kai nu kai karata rehta hata” (You were wasting money trying different things out while I was looking after the farm. He would stay in the house, tinkering with one or the other thing).

The work that Jayaben put in the fields inverted traditional gendered occupational norms and afforded Bachubhai the time to combine his interests in electronics and fabrication to produce solutions such as the LED-based voltmeter and the mini-tractor. Using his father's fields to test such technologies required Jayaben to transgress gender-based occupational boundaries to adhere with gendered family responsibilities. Jayaben substituted for Bachubhai in the fields and worked as a *khedut* (farmer) to fulfill her roles as a dutiful wife and responsible daughter-in-law. With Jayaben's assent, of Bachubhai's sons registered a private company to produce and market an herbal solution that Bachubhai had developed for loosening rusted pieces of threaded metal. Bachubhai himself agrees that his wife has played a key role in helping him realize his ideas.

Articulation work as empathic cooperation

Sahayog (empathic cooperation) describes the innovators' reflexive interpretation of the articulation work performed by family in direct and indirect support of DIY innovation. *Sahayog* is a rhetorical response to family members' material and relational articulation work signifying encouragement and approval of hobbyist tinkering, unpaid and underpaid work.

Bhanjibhai's wife who says she has always encouraged him to take risks when working on the innovation. As she recalls: “I have no idea what time he will return once he leaves home. I know he likes to spend time working on building new things and have never asked him to cut back on his *sanshodhan* (research) to spend more time with the family.”

Bharatbhai recalls how both he and his brother were involved in their father's workshop from a young age:

Growing up, Ashwin and I would always spend time with Bapu when he was working on building different implements. When he got the funding for redesigning the Aaruni he discussed the plans with us. While Ashwin is now with the postal service, I have continued to manage the day-to-day operation of the workshop.

Bharatbhai continued Amrutbhai's fabrication work but commutes between Keshodh, the town where he lives with his family nearest to the family workshop in Pikhori. He finds the commute challenging but wishes to continue his father's work by developing innovative technologies that benefit people. He does not view himself as being limited to Pikhori, Keshodh or even Junagadh and instead sets his eyes on designing technologies that may benefit people across India and even abroad.

Mansukhbhai interprets *sahayog* as the substitutive enactment of different roles sustaining material practices with the maintenance of social relations and sharing of emotional support.

We do innovation, we work but family's sahayog is especially important and necessary. Only then you can achieve success in innovation. The family's sahayog is necessary. If the family does not support, you may not succeed. You need sahayog from your father, your mother, children, and wife. The other work at home should not stop because of ... the samajik (social) kaam (work/responsibilities).

Mansukhbhai's mother not only helped him with the running of the workshop but also consoled him when during times of financial distress:

She helped me holding my hand. She gave me a lot of saath (support). When I was under a lot of debt, she would tell me to take rest, but she would take charge of the work.

Mansukhbhai's wife and children remained sanguine regarding their economic instability, disavowing criticism from local community members that followed in the wake of Mansukhbhai's initial failures in developing and selling working products. As Mansukhbhai explains:

People used to say again and again that you are pagal (crazy). So that was creating an obstruction for me. I began to think have I really gone crazy. This was preventing me from working fast. My family never said a thing. My wife helped me again and again. She says business works like this... it has ups and downs. Not only my wife but also my children are also in complete agreement (sahamat) about her sahayog. They say, papa you are doing very good work.

On the other hand, Kalpeshbhai's family were unwitting witnesses to the stress accumulating from his debt-ridden attempts to design innovative machines for metal bending and agricultural processing. He recalls attempting to shield his family from the financial stress he experienced during innovation: "When I had debt my family didn't know I have so much debt. But they knew I had lot of psychological stress."

Articulation work as instrumental assistance

Other families highlighted the tensions arising from financial uncertainty caused by conscious participation more and less visible forms of articulation work for DIY innovation in the family occupation.

Mansukhbhai recollects the difficulties he faced in receiving his father's approval to design a press that mechanized the production of *tavas* (clay skillets):

I used to make 300 rupees a month, at the time I decided to take 50,000 in loan. My father and mother did not like it. They feared that I might fail.

Raghavji advised Mansukhbhai to leave the family occupation:

I used to tell him don't work with maati (clay) when he used to study. He was our only son. He used to like to wear fashionable clothes so I used to think he couldn't do this kind of work that gets your clothes dirty.

In hindsight, Mansukhbhai empathizes with his father's disapproval of the labor-intensive, high-volume, low-margin work in pottery:

My grandfather and father used to work as potters, but they left this job. The work you do [as a potter] is hard work. You would not get paid for your work but in grains. You get 10kg of wheat as payment for your labor. We would then sell this grain in order to raise the money for other household expenses. It was a very difficult life.

Nazim Shaikh's father expresses distress over his son's lack of interest in pursuing paid employment:

It is not so simple. [He] is married with a kid. What can be done in 5000 [rupees]? Nothing! You get one bout of disease, that is 2000 [rupees] right there. Our daughter-in-law is unwell. There is no income. [Turns to Nazim] You are working your mind and hands a lot. But you need income. I use my mind for money. [Turns to me] If we keep our hand behind his back and try to complete his work then who takes care of the rest? He says you don't give money for innovation. Tell me should I buy food for the house or give you money? He is playing with his fate. If it works out, great. He has a lot in his mind. He does not tell us. We don't know what he does. We find out through the newspaper. We say you are going crazy doing this. Get a job. Do some business. But [he] says no if I work then I will do only what my heart my mind says. I don't have much mind. All I know is how to run the house. How to earn money. This is what I think about. Even I have a good mind. I have a strong mind. I would also do something and show. But I have a family behind me. Who will take care of them?

For Arvindbhai, family is a sink for time and energy that could otherwise be devoted to innovation. The best assistance that his family can provide is to give him time and space to think freely on his ideas. Arvindbhai's prefers less visible articulation work rather than the active participation by family members in DIY innovation.

One important thing in innovation is that ... it is dimaag ka kaam (mind/brain work) ... you have to sit in a silent space and sit alone to work. [I] cannot be in tension or stress. [I] cannot be disturbed. If the link breaks, you're thinking about something, someone calls you, then your mental work is stopped... you are occupied with something else... [it could be] samajik kaam (social responsibilities), outside work, neighbors. [That is why] when the kids had gone to school, [when] my wife a schoolteacher would go to school... I would sit at home and work. I draw the curtain and start the fan and sit to work. A steady mind is necessary. Ekant (solitude) is necessary.

Arvindbhai's wife Ushaben explains how she *has* to work as a schoolteacher to support the family and indulge Arvindbhai's DIY pursuits.

It's not like working as an innovator guarantees you a steady income. How is this house being run [then]? Fortunately, I have this [teacher's] job and I make twenty-thirty thousand [rupees] a month which helps pay for the household expenses and children's education. Life for an innovator's family is very hard. You have to make sacrifices.

Ushaben is not opposed to her husband spending time, money and effort innovating. She expresses pride in her husband's preference for working in isolation on piecework:

The special thing about him is that he will never seek outside help. He will work for 4 days, a few weeks or months but he will work himself to save labor. He understands that his means are limited and he has to do more by himself – he has to suffer this constraint.

Ushaben provides *madat* (assistance) to Arvinbhai by taking on responsibilities out of a perceived lack of choice rather than as a proactive or self-determined enactment of *sahayog* (empathic cooperation).

The family is clearly faced with a dilemma when the innovator insists on expending the family's resources toward the innovation effort. While Mansukhbhai, Bachubhai, Bhanjibhai, and Amrutbhai enjoyed *sahayog* of their family members who express a willingness to deal with the uncertainties and risk involved in making something new, Kalpeshbhai, Nazim Shaikh, and Arvinbhai's families illustrate the difficulties that the innovator imposes upon his family members by choosing to innovate. While Kalpeshbhai chose to continue his activities without holding his family members in confidence regarding the extent of his indebtedness, for Nazim Shaikh's father and Arvinbhai's wife the economic stability of the household clearly holds more importance than innovation. The roles they assume are less out of enthusiastic support for the innovator's creative pursuits than out of a stalemate ensuing from the innovator's refusal to engage in paid employment or business.

Discussion

DIY in non-Western households on the margins is driven by necessity and hobbyist interest rather than prosocial intent. Hobbyist problem-solving through making and repair on the margins draws on skills and knowledge gained through socialization into subsistence-based family occupations. Family occupations include repair professions and artisanal trades historically practiced by communities sharing caste- and religious identity.

Parents, spouses, and children provided care in the form of technical, logistical, financial, and emotional support. They provided time for innovator to think and work by addressing logistical concerns, taking on greater financial responsibilities toward the household, and dealt with financial instability brought on by innovators' participation in DIY innovation. Innovators acknowledged such support was crucial in helping the family tide over times of distress.

Family members talked about their experiences performing articulation work for innovation as assistance or empathic cooperation. Members, in particular spouses expressed reservations about the economic viability of DIY and implied participation in DIY was both a choice *and* a prevailing condition of the household.

Domestic articulation work for DIY on the margins

Domestic articulation work during DIY innovation involves routine and contingent paid and unpaid labor in direct and indirect support of the innovation. Such work lurks in the shadows of linear institutional narratives that depict grassroots innovators' capricious journeys as a series of "Eureka" moments. Spouses and mothers shouldered traditional domestic responsibilities related to cooking, cleaning, and childcare. They also transgressed traditional gender roles, undertaking paid and unpaid labor at home and outside to underwrite the time and money spent by DIY makers.

Reconceptualizing care during making

Family members enacted care as non-users, users, and co-designers, helping innovators deal with negative social appraisal and financial distress. Care during grassroots innovation is not only an antecedent or intended outcome for design, but also performed in the family as material, relational, and emotional articulation work seeking legitimacy and coordinating dyadic effort through role substitution.

Care during grassroots innovation is sought and not only enacted by makers. Families demonstrate the heterogeneous and often contradictory ways in which normative and transgressive domestic roles are recapitulated in articulation work as willing and reluctant care.

In western families, financial reasoning justifies transitional and non-traditional family roles. Such privileged participation in western hacking collectives enables enactment of classed and gendered roles and identities such as hacker-moms (Daniela K. Rosner & Fox, 2016) and stay-at-home dads (SAHDs) (Ammari & Schoenebeck, 2016). For non-Western family members, care during making is more than a

“speculative commitment to neglected things” (Toombs, Bardzell, & Bardzell, 2015), p. 2). Unlike stay at home dads (Ammari & Schoenebeck, 2016) male innovators struggled to reconcile their gendered identities as breadwinners with their participation in non-income generating creative work.

Spouses and mothers played key direct and indirect roles caring for innovation through articulation work. Gender role transgression through participation in paid labor or physical labor in the field constructed spouses as different but not equal, rather than equal yet different (McCarthy & Wright, 2015), enduring emotional labor and material scarcity with technical, financial, and reputational risks and challenges.

The involuntary transgression of gender roles in implicit support of innovation suggests that: (a) instrumental care may be accompanied by relational neglect, and, (b) collective activist impulses are not necessary for social norms to be challenged.

Current care ethics typologies don't account for cases where care provision is involuntary. Involuntary care can be overt and directly perceivable as care, such as when Arvindbhai's wife supports the family through her earnings. It may also be covert in the sense of Bachubhai's wife toiling in the fields despite gender norms proscribing married women of her caste from working in the field. The relative visibility of the act's foregrounded meaning as a compassionate response distinguishes reluctant care from its more empathic counterpart.

These findings suggest a need to study the social and economic implications of enacting care through material engagement (Crivellaro et al., 2016). The sustainability of making as a sociotechnical solution (Roedl et al., 2015) on the margins depends on the extent and manner in which family members enacting care for DIY practices reconcile its subsistence, hobbyist, and prosocial antecedents.

Conclusion

Making occurs everyday at the grassroots. Family is essential for sustaining making at grassroots as subsistence work and hobbyist endeavor through empathic care. Family precedes community, culture, movements, and institutions as a key organizational form for DIY innovation. This is perhaps more true in the Majority World, where informal ingenuity in the face of lack is an approach to negotiating material constraints is likely an inescapable facet of everyday life borne of necessity than voluntary hobbyist endeavor. Participation in DIY on the margins is accompanied by motivational paradoxes. For instance, grassroots innovators desire better economic prospects but are reluctant to continue paid work opportunities. Sustaining making in the Majority World requires attention to questions of embeddedness and is not just a question of providing access to production tools. Enabling members of underrepresented categories participate in technology design and production requires not only an acknowledgement of the skills and expertise that underrepresented members possess, but also an interest in learning of the contexts in which they arise.

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