Learning to Fix: Knowledge, Collaboration and Mobile Phone Repair in Dhaka, Bangladesh

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ABSTRACT
Practices of technology repair in developing country contexts play crucial and often overlooked roles in supporting ICTD goals of access and sustainability. They also constitute complex and neglected sites of technical skill, knowledge, and learning. Building on original ethnographic fieldwork, this paper explores the explicit, tacit, and social knowledges that shape practice and expertise in the mobile phone repair markets of urban Bangladesh. We document forms of learning and collaboration central to the production and innovation of repair skills and knowledge, and show how these processes operate at the intersection of global knowledge flows and local efforts to access, contextualize and situate that knowledge. We conclude by arguing for repair as an underappreciated site of third-world technical practice and expertise, and reflecting on how ICTD research might better take such practices into account.

Author Keywords

Repair; Learning; Craft; Skill; Tacit Knowledge; Ethnography; Bangladesh

ACM Classification Keywords

H.1.2. Human Factors

INTRODUCTION
Knowledge, learning and collaboration have long been central to the forms of technology use and adoption at the heart ICTD research. Participatory design and action research traditions of ICTD work have sought to build collaborative partnerships between users and designers, in the interests of more usable and locally appropriate forms of design. Work on technology adoption has sought to understand how technical skills and knowledge are shared and transmitted among user populations, enabling or disabling the adoption of new tools in developing country contexts. Access advocates have explored complex and distinct forms of sharing and collaboration that have disrupted western assumptions around the relationship between users and devices (and in particular, models of individualized ownership that may be inappropriate or limiting in many third-world contexts). Taken collectively, these findings have driven important research and design insights in ICTD scholarship, and helped to surface features of post-colonial computing environments that set them apart from their western counterparts.

But learning and collaboration are no less central or complex in other technological moments and practices, including those centered on technology maintenance and repair. The field's traditional design orientation has tended to obscure this work, leaving a long list of important and interesting questions unasked. How do actors in third-world environments build the skills and experience needed to deal effectively with broken or malfunctioning devices? How do repairers acquire the knowledge and skills needed to restore function and value to broken tools and infrastructures? How do people work *together* around repair, pooling and sharing knowledge, skill, and experience? And how are collective bodies of repair knowledge built, shared, updated and sustained over time, at both the local and trans-local levels?

This paper seeks to address these questions through original ethnographic fieldwork with mobile phone repair workers in Dhaka, Bangladesh. We start by reviewing HCI and social science literatures on repair, including older and newer bodies of work that have called attention to maintenance and repair as complex and constitutive sites of collaborative technological practice. We then turn to theories of learning and collaboration that have shaped our understanding of working knowledge in contexts of skill-based material engagement. After briefly describing our methods, we turn to findings from our fieldwork, offering brief biographical sketches of three representative figures in the mobile phone repair worlds of Dhaka. We describe three distinct forms of knowledge around repair – explicit, tacit, and social – and the forms of learning that characterize the transmission of each. We conclude by tying our findings back to larger ICTD concerns around technology access and sustainability, and offering recommendations to ICTD researchers for how they might better account for practices of repair in their work.

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BACKGROUND AND RELATED WORK

While its subsequent history of attention has been spotty, work on technology repair in the broader information science field in fact goes back several decades. Leveraging long-standing ethnomethodological interests in social and conversational repair (see, inter alia, Garfinkel [1], Goffman [2], Sacks [21]), Lucy Suchman's seminal contributions around the relationship between formalized plans and situated actions were built on the collaborative experience and challenge of photocopier repair work at Xerox [23]. Julian Orr [14] extended this work in a learning direction, studying the central role of 'war stories' and other informal means of knowledge flow among repair workers as a central conduit of learning outside of the formalized channels of official technique and procedure.

More recent work has built on these foundations to explore motivations, values, and practices of repair across a wide range of contexts. Research by Rosner and colleagues [18,19,20] has explored connections between repair, materiality and the longevity of artifacts; between repair and gendered conceptions of technology use and identity; and the material and ideological flows attached to repair work in global development projects. Jackson and Kang [8] have argued for links between repair, creativity and collaboration in artistic production, and their connection to questions of care and responsibility in human-object relations more generally. Separate field programs in Namibia [9,10], Uganda [4], and Bangladesh [7] have explored patterns of infrastructure, practice, collaboration, and local art and craft constituting local "repair worlds" along with their connections to global flows of knowledge and infrastructure around technology. Rangaswamy et al.'s [17] study of mobile phone repairers in Mumbai has argued for the role of repair technicians as agile and innovative producers (rather than passive and unskilled consumers) of technology. Writing more broadly, Jackson [6] and Graham and Thrift [3] have argued for moments of breakdown, maintenance and repair as key elements in human relationships with technology, with deep and formative connections to questions of innovation, justice, and sustainability.

These recent and older bodies of work suggest deep and generative connections between repair and the forms of technology design, use and adoption that have more typically occupied ICTD scholarship. They point to the relationship between repair and other values – innovation, access, and sustainability – long central to ICTD concern. They explore have pointed out tensions between the forces and motivations that push people toward fixing, and the complexities that confront the work once engaged. And they have suggested the deeply *collaborative* nature of repair, showing how people address complex challenges of repair through the sharing of knowledge, skills, and material resources at scales ranging from the workbench and lunch table to large transnational networks. If this is true generally, it's even more pronounced under the conditions of many third-world computing environments, where devices, systems, and infrastructures may be particularly prone to breakdown and failure, resources may be in short supply, and repair-vs.-replace decisions may follow a very different economic calculus.

If this work explains the importance and complexity of repair along with its distinctive role in the third-world computing environments, it also leaves important questions unanswered. For example, while we know of the presence and importance of global flows of technical knowledge and material around repair, the precise mechanisms by which such global resources interface with repair operations at the local level remains unclear. Nor is it clear how local repair communities are formed, organized, and reproduced over time. Finally, the forms of learning and collaboration by which repair skills and knowledge are circulated and sustained within local repair networks require further elaboration.

To answer these questions, we turn to classic work on learning and collaboration in the social sciences. An important part of the skills mastered through repair fall under the category of tacit and craft knowledges, referenced by the fact that, as Polanyi [15,16] argues, "*we can know more than we can tell*". He illustrates this with the example of learning to ride a bike. On one hand this may be informed by abstract conceptual knowledges relating to gravity, momentum, centripetal and centrifugal forces, the mechanics of chain and pedal, etc. But beyond this stand hard to describe elements of look and feel that constitute the actual knowledge of bike riding for those who have mastered the skill. Scholars of craft like Sennet [22] have explored the nature of craft work, forms of skillful material engagement that embed relations of care, value, and pride in work that link the subject and object or medium of work. Resistant to formal specification, tacit and craft knowledge is instead embedded in the practical accomplishment of work, and often flows from teacher to learner, master to apprentice, through processes of observation and experience wrapped in trust, care, and respect.

Repair practice may also depend on forms of social knowledge situated in professional or craft-based communities of work. This argument is most powerfully made by Lave's [11] and Lave and Wenger's [12] analyses of the learning processes attached to "communities of practice" that may form around craft and professional work of all kinds. Lave and Wenger show how communities of practice are often characterized and sustained through apprentice relations responsible not only for flows of knowledge from "master" to "apprentice," but also the production of social order, norms, and hierarchies and the reproduction of community skill and knowledge as a whole. Under this conception, learning is not a simple and one-way absorption of factual information, but rather a process of building a newcomer (though "legitimate peripheral participation") into a fully functioning member of a

community through involvement. Apprentices and newcomers learn the norms and values of the community by helping and observing the existing members, situate themselves in it, and earn their membership by showing their competence to exist in and contribute to the community.

Taken together, prior ICTD and information science work and the contributions of Polanyi, Sennet, McCullough, and Lave and Wenger reviewed above provide deeper understanding of the nature of the learning processes involved in the production and transmission of repair knowledge. At the same time, they connect the nuances of the learning process to broader issues associated with the profession, culture, and social organization of repair work. In the empirical descriptions that follow we use these theories to see how repairers establish relationships with their tools and techniques, how they tune their hands, eyes, and hearts with the technical forms of digital artifacts, and how the learning processes associated with repair work operate to convert apprentices to skilled repairers and fully-fledged members of the repair community. We argue that this reproductive repairing process is essential in sustainable development, and deserves proper attention.

METHODS AND FIELDSITES

Our study was divided into three broad phases. In the first phase we conducted 58 semi-structured interviews with mobile phone repair workers at 10 different sites in Dhaka, Bangladesh, outlining basic patterns of repair activities, identifying main repair sites and networks, establishing long-term relationships with informants, and refining the research questions. The next phase consisted of 4 month ethnographic field study conducted in Summer 2013, visiting major repair sites, observing ongoing work, and conducting an extended series of interviews with a select subset of participants (from which the biographies below are partly constructed). Our informants included repair workers, novice apprentices, repair workshop owners, engineers graduated from universities of polytechnic institutes, repair customers, and e-waste collectors and vendors. This phase also included participating in a month-long training program at a local mobile phone repair-training center, and a 3-week apprenticeship at another repair workshop under a senior repairer. Our third and final phase of work included 70 semi-structured interviews with repairers and clients at 10 different repair shops in Dhaka, focusing on questions of practice, value, and collaboration. All of our interviews and field interactions were conducted in Bangla by two Bangladeshi researchers, and later partially translated and transcribed into English. The observations produced textual notes of several hundred pages, and more than 1000 photographs in which repairers demonstrated and documented key techniques. Most of our investigations focused on the craft and expertise involved in repairing, and the process of learning those.

The following sections detail our findings around collaboration and learning as practiced in the mobile phone repair worlds of Dhaka, Bangladesh. We begin with an overview of the organization of work in this space, describing the sites, resources, and networks through which repair work is accomplished. We then draw on interviews and field notes to construct biographical sketches of three of our informants who, taken collectively, speak to the range of backgrounds, experiences and trajectories to be found among repair workers in our study. While later parts of the paper will detail specific forms of skill, knowledge and learning central to repair work, we argue that biographical accounts of the sort offered here (and practiced elsewhere by Linde [13], and Weiss [24]) are important to understanding both immediate practices of learning and skills transfer, and the broader processes of identity, meaning and social organization that are central to repair as practice and as a way of life.

Background: Basic Repair Activities in Dhaka

The mobile phone repair worlds of Dhaka include sites ranging from high-end repair shops at general-purpose shopping malls to clusters of independent repair operations occupying a whole market. The high-end service centers attached to multinational brand companies such as Nokia, Siemens, and Maximus usually stand alone at large shopping malls or business complexes, and perform warranty fixes of phones still covered under service contracts. While they usually recruit engineers graduating from low-ranked universities or polytechnic institutes, they tend to perform a simple and limited range of repairs, usually limited to the detection of non-functioning or problematic handsets and replacing them with new units supplied by the company.

A much larger range and volume of repair takes place in the independent and informal sectors. Some of these repairers have their own mall or roadside shops, while others operate alongside other repair operations in large informal markets like the Gulistan Underground Market. While a subset of these workers, like Akbar., draw on repair skills accrued while abroad, most rely on knowledge and connections earned through apprenticeship. Few if any have formal academic training in technology, and their knowledge of mobile phone operation in its theoretical or engineering dimensions is often limited. In comparison to the brand repairers, workers in the informal sector deal with a remarkable range of problems, from broken screens and non-responsive keypads to overheating and failed or spotty network connections. They are also much more prone to perform actual repair (as opposed to replacement) work, going to often extraordinary and innovative lengths to diagnose, correct, and work around the range of breakdowns and problems encountered.

At the immediately material level, sites in the brand and informal repair sectors are linked in turn through a third community no less integral to the collaborative practice of

repair. Referred to locally as "bhangari" (from the Bangla word "bhanga," meaning broken) they circulate through the city, visiting repair shops and buying or collecting broken parts and devices (cases, motherboards, batteries, keypads, etc.) at low or bulk prices. These materials are then sorted and resold: some on to other repairers looking for parts or raw materials, and others on to groups of Chinese recyclers, who, it is rumored, export the materials for processing and disposal in China.

These local repair networks are connected in turn to global networks of consumption and repair, through both materials and knowledge. The electronic devices used in Bangladesh are almost entirely designed and manufactured in other countries; as a result, forces and trends emanating from abroad may drive local uses and repair of technology. The tools and spare parts used by repairers (hot air guns, soldering irons, various ICs, etc.) are mostly imported from other countries, especially China. As we have seen, the material by-products of breakdown and repair (including forms of waste) may also be tied in to regional and global recycling markets. Repair knowledge is similarly networked at the global scale. Some local repairers receive their training abroad, and then redistribute this knowledge through teaching or training of apprentices. Some repairers also draw on resources from the Internet, including the repair boards of the GSM forum, to borrow and sometimes contribute to global discussions around new techniques, designs, and known flaws or issues (though barriers of access, language, and literacy can sometimes limit this connection). In the section that follows we explore the stories of three representative figures, who occupy and constitute the contemporary repair worlds of Dhaka.

Biographies

1) Akbar

Akbar is a 49-year-old senior repairer and trainer of mobile repairing who works at Nahar Plaza, Dhaka. He was born in Kishorganj, a town 5 hours drive away from Dhaka. He developed a keen interest in electronic devices with the help of his father who also loved electronics, and taught him the basics of current, voltage, and power at a very young age. While growing up, Akbar met an appliance technician who taught him about motherboards and Integrated Circuits (ICs). As a student in high school, Akbar reports always producing small electrical devices for his science projects. But he ended up going into accounting as this was considered at the time a more promising job market. While studying for his Masters degree in accounting, he took a part-time job at company selling closed circuit cameras and televisions. After graduating, he moved on to full-time work in the telecom industry: first at a company providing PABX phone connections to home and offices, and two years later at a government office providing mobile network support for military units. All these jobs helped Akbar learn the basics of wired and wireless networks.

On the basis of this practical knowledge, Akbar applied to a job at a Saudi Arabian telecoms company, and was the only non-engineer selected from over 108 candidates. The company sent Akbar to Thailand for a six month training period, where he learned about the function and repair of mobile phones from experienced Thai electrical engineers. He then moved to Saudi Arabia for employment, working with a multinational team that included engineers from Bangladesh, India, Pakistan and China overseen by a team of Korean supervisors. Akbar describes his learning during this period as follows:

"*You should watch them (superiors) carefully, although most of the time you will not understand anything. You just see and remember. ... A good learner is he, who remembers everything and tries to understand things later. Also you need to have a good relationship with the superiors. ... When they will see that you are trying to understand things, they will help you. But if you pretend like you understand everything, they will be pissed off. Again, if you show no interest in learning, they will be disheartened.*"

After two years in Saudi Arabia, Akbar received news that his father was sick and decided to return to Bangladesh. Using funds and skills acquired during his time abroad, he decided to start a mobile phone repair training and servicing center at Dhaka. This was in 2001, when mobile phone repair in Dhaka (and mobile phones themselves) were still relatively scarce. Akbar built his training center around the model he had seen in Thailand, structured around a balance between theoretical and practical knowledge. He started with two shops, but soon expanded his business by renting another three. By the time of our fieldwork in 2013, Akbar reports having graduated more than 7000 students, most of whom went on to start repair business of their own in Bangladesh (though others followed Akbar's own earlier path and went to Canada, the US, or Middle East to earn more money). Beyond his training activities, Akbar also maintains good relationships with parts and equipment importers and e-waste collectors, and runs a small retail shop for repair tools and accessories that is well-known within the local repair community. He also runs his own Bangla repair blog for local repairers who do not understand English. While his training business has declined somewhat since around 2008 – an outcome he blames on growing and sometimes dishonest competition in the market and a growing flood of cheap and disposable Chinese handsets that undercut the price and market for repair – Akbar continues to dream big. He tells us he hopes to start his own mobile phone assembly factory in Dhaka in the very near future.

2) Rupam

Rupam is a 35-year-old mobile phone repairer working at Eastern Plus Market, Dhaka. He was born and brought up in a lower middle-class family in Jinjira, a suburb of Dhaka. He was sent to school, but never considered himself a good fit there and left after grade 9 to start work in an ornaments

shop. The job was easy, but low paying, and faced with a family financial crisis, he resolved to find a better paying job. Around the same time he tells us, Rupam developed a crush on a girl. To impress her, and to take advantage of the rapid growth in mobile phone use then underway in the country, Rupam decided to become a repair technician. This proved difficult to do without prior skills, experiences or connections. So, he started working with one of his friends who worked as an appliance repairman. Rupam's task was to help his friend by handing him tools and taking care of the shop. As he worked, his friend would explain to him what he was doing, and thus he got his first lessons on repairing. When their relationship fell apart, Rupam started spending his time at the repair stalls of the Stadium Market, where he would stand and silently observe the repairmen at work. Eventually, Rupam explained,

"*If you stand at the same place for two days, people will look at you. At some point somebody will come to you and ask, "Who are you? What do you want?" That also happened to me.*"

Rupam became friendly with the owner of one of the repair shops. When the shop-owner learned that Rupam was fluent in the dialect of old Dhaka, which many customers spoke but the shopkeeper struggled in, he was given a job greeting customers, receiving orders, and explaining the reported problems to technicians at the shop. While working in this way, Rupam would watch how the repairers worked. One day Rupam brought a broken mobile phone of one of his friends to the shop, but found no repairers available to fix it. He decided to attempt a technique called 'servicing' which he had seen the repairers perform many times before. The technique worked, and soon after the other repairers started to take his help in their work. Rupam worked there for 2 years. During that time, he heard about a senior repairer who had returned from abroad and was offering a training course on ICs. He took the course and became familiar with the names and functions of the ICs.

Soon after, Rupam became friends with an expert repairer in Stadium Market. They decided to open a shop together at a nearby location. Rupam worked at the new workshop while his friend continued on at the Stadium market. Since Rupam's grasp on repair techniques was still limited, he would often go to his friend for help, who would fix the device but not show Rupam how to do it. Rupam thought this had been the way his friend would try to maintain his power over the business. However, Rupam started to learn newer things on his own by trial-and-error. He also started drawing on help from Internet. He recalled the first iPhone he unlocked in this way:

"*A client came to me to get his iPhone unlocked. I did not know how to do that. I went to my friend. He told me to leave the phone to him and he would fix that later. But the client was waiting at my shop and I had no way to leave the phone to my friend. So, I searched on Internet and got a video on doing this. I followed that and it worked. The client was happy. I also learnt how to unlock the phone. It was not a difficult task. But my friend did not want me to learn that*."

A few days later, Rupam had a quarrel with his friend and he left the shop. Then he started his own business at Eastern Plus market at Shantinagar. He has now been working at that shop for more than 5 years, and has continued to develop his skills, techniques, and customer base. He has also continued to build connections with other repairers, e-waste collectors, IC importers, and others in the repair world. He reports being happy with his work, and enjoys the connections and respect it offers him in his local circles.

3) Jahangir

Jahangir is a 38 years old bhangari business owner at Elephant Road, Dhaka. He was born and raised in a middle-class farmer family in Sylhet, a 4-hour drive from the capital. He left school after the 4th grade due to lack of interest and his family's financial constraints. When he was 12 years old, one of his maternal uncles, who ran a bhangari business in Dhaka, visited Sylhet and invited Jahangir to join him in the capital. Jahangir decided to take the offer, both for the financial reward it offered and for the possibility of migrating abroad from Dhaka it might offer.

From his uncle, Jahangir learned the basics of the bhangari business, traveling the streets of Dhaka and buying discarded objects from households, which he would then resell at a higher price. Mr. learned how to approach unknown people, inquire about discarded objects, and bargain effectively on the price. He said,

"*People often cannot remember that they have discarded objects at their house. So, you have to ask like, "Do you have old newspapers, broken mobile phones, or torn bags? Do your kids have broken toys?" Then they will be able to remember. You have to be intelligent enough to guess what sort of discarded objects a person can have at his place."*

He also learned how to categorize the various objects collected by material type and market values. He realized that electronic devices were more profitable than other businesses, and that offices were better places to find electronic wastes than households. So, he stopped following his uncle and started going to the offices. Jahangir's uncle would sell the collected objects to a wholesale bhangari. Mr. H noticed how his uncle would maintain good relationship with that wholesale bhangari, and he also got himself introduced to that person. Later that guy became the main client of Jahangir.

It was not easy for a young boy to go to big offices and buy discarded objects. He spent a lot of time observing and learning how people dressed and talked around the offices he visited. He started dressing and talking in the same way, and found that it helped him source materials more effectively. He also learned how to compete for tenders when Government offices would sell their old electronic devices at steep discount. With his new profit he was soon

able to rent his own shop and recruit younger bhangaris to collect discarded objects on his behalf, sending them to repair shops, government offices, universities, and households.

He explained the core knowledge of his business to us as follows: "*The challenging part is to get the broken things that hold value. Selling is never a problem. There are always enough parties to sell things.*" Determining the worth and condition of a discarded technical object is a relatively challenging task. Between two discarded motherboards, the one with more metal and less damaged ICs often holds more value on local markets. Over time, Jahangir had learned to estimate the value of a discarded motherboard just by looking at it and touching the parts. He developed this skill through his relationships with repairers and recycling wholesalers, and through years of experience in the collection and resale of broken electronics.

Summary

As these stories suggest, entry into the repair professions follows a wide range of paths and motivations, from the familial, affective and personal to the economic and instrumental. But in all cases learning is central. Knowledge and skill play a central role in shaping the prospects for employment, stability, income, status, and future work trajectories for all members of the broader repair worlds in Dhaka. We have seen how people train themselves in different ways and how local and international networks, corresponding community, contemporary society, and communication technology play roles there. Learning remains an essential companion throughout the career of these people to keep them updated with changing technologies, skill sets, and the social and economic orders around repair. However, several practical challenges coming from issues including professional jealousy, lack of jobs, and illiteracy often limit their access to the community, and hamper the process of learning and developing skills.

Another important takeaway from these biographical sketches is the understanding of the reproduction process of repairer communities. Through the practices described above, repairers not only learn to support their existence in the community, but also, at some point, start sharing their knowledge with others through social practices that contribute to sustaining and reproducing the broader repair community. This contribution is collaborative both in the form of its immediate practice (apprenticeship), and in its broader contribution to sustaining and reproducing the community of repair that is essential to computational practice and infrastructure in Bangladesh. Beyond the transfer of necessary knowledge and skill, learning to fix is also about learning to *be* a fixer, acquitting oneself well and responsibly within both an immediate professional and wider social community. Learning processes in the repair community should therefore not be understood just as access tool, survival mechanism, or road to a sustainable livelihood (though they are all these things as well). Rather they should be understood as historical processes of sharing and enculturation through which collaboration, sustainability, and innovation are accomplished.

TYPES OF KNOWLEDGE AND LEARNING PROCESSES:

As the biographies in the previous section make clear, knowledge and learning are central to practices of technology repair, reuse, and recycling in Dhaka today. But the knowledge and learning required come in several different forms or varieties, which competent repairers must master and blend. This includes explicit or conceptual knowledge of phones in their technical or schematic sense (knowledge of circuitry, function, etc.). But it also includes forms of tacit, craft, and social knowledge no less central to entry and long-term success in the field. The following subsections explore each of these knowledge forms in turn, along with the core processes and mechanisms of learning by which they are shared and transmitted within the wider repair community.

Explicit Knowledge

By explicit knowledge we refer to the largely conceptual knowledge that lies behind the effective repair of broken devices. This includes information on the different parts of the mobile phone, how they're related to each other, the functional connections (including discrete paths in the circuitry) that link them into an operational hole, and the larger schematic similarities and differences that unite or separate different phone models. Repairers in Dhaka gain this knowledge in different ways, mostly from their mentors during their days of apprenticeship, and then from sources like Internet, manuals, and friends.

Akbar's training center offers short course on repairing mobile hardware, which includes both the 'theory classes' and 'practical sessions' (the terms, 'theory class' and 'practical sessions', are adopted from Akbar's training center). One of our team members took this one-month long course and learnt about the structure of this explicit knowledge from the theory classes. Most of the instructions would follow a particular format. Akbar would introduce the students to a problem that could occur in a mobile phone, for example: the battery is not charging, or no network connection. Then he would tell which IC on the motherboard would be responsible for that. Then he would tell what action was required to fix or replace that IC. So, essentially the structure of the information had two basic mappings in it: i) mapping a problem with a IC, and ii) mapping a IC with the solution. The following field note taken at Akbar's class should make this structure clear.

"Akbar is explaining the repair works involved with 'Polaroid capacitor" today. He says,

"*Many times you will get complaints from the customers that their phone is not holding charge. If you put the phone on charge that shows the phone being charged. You can even use the phone as long as you want while the phone is*

charging. But as soon as you remove the phone from the charger, all the charge goes away. This is a very common problem, and an IC called "polaroid capacitor" is responsible for this. The responsibility of this capacitor is to hold the charge. When this capacitor is broken, the phone fails to hold charges. The only solution is you have to replace this capacitor with another one collected from another motherboard. But, first of all, you have to identify which one is the Polaroid capacitor on the motherboard. Polaroid capacitor is the yellow IC on the motherboard, with a brown patch. You can easily identify it, because it is slightly larger than the other ones. The side that has the brown patch is the "positive side"."

Akbar would try to make the information as general as possible, so that it could work for mobile phones of any manufacturer. If there were exceptions for any particular manufacturer, he would mention these too. While introducing the function of the ICs, Akbar often used metaphors. For example, he used the metaphors of a "river" and "tube-well" to explain the difference between the functions of a diode and a transistor.

Besides these sorts of lessons from senior repairers, repair workers in Dhaka often take help from online resources. The Internet has spread out the country recently, and repairers often browse Internet through their mobile phones or in some cases through some very old refurbished computer that they collected only for this purpose. Manuals are another source of explicit knowledge for Bangladeshi repair workers, valued in particular for their diagrams of motherboards and crucial information on the location and function of ICs.

Tacit Knowledge

In our fieldwork with repair communities, we observed the necessity of tacit knowledge for repairing. In most of the cases, they learn this through observation and imitation during their apprenticeship. They learn things first by observing their superiors, and then by imitating them. They also learn through their experience while making an attempt to perform the task. The following field note taken at Akbar's practical session can give a better insight of this learning process.

"Akbar took a motherboard in his hand and started to demonstrate us how to remove an IC from the motherboard and how to attach an IC on a desired place on the board. ... Akbar was holding the hot air gun in one hand and forceps on the other. The forceps were gripping the IC on the board that he was trying to remove, and the hot air gun was blowing hot air onto that. In a few seconds the paste started melting and the IC became lose. Akbar pulled the IC off the board using the forceps…. Then he showed us how to place the IC back to its original position. Next, he asked us to remove and then place back a small resistor on a motherboard. This was the first time I was holding a hot air gun. I was just trying to follow what he had just done. ... Placing that small resistor at its original position needed very sound attention. I tried to get eyes closer to the IC so that I could see it better, but it was not possible because of the hot air gun blowing hot air. My hand was trembling, and I was struggling to grip the chip with my forceps. But after a number of failed attempts, finally I succeeded ..."

Figure 1: An expert repairer is practicing at his desk in Gulistan Underground Market

The above example demonstrates how observation and imitation contribute to the acquisition of hard-to-describe skills. We bring in another example here to clarify the nature of tacit knowledge and the role of the master in its learning process. The following example is taken from a field note written during the apprenticeship of one of our team members at Rupam's workshop.

"... Then I started brushing the board. Rupam was closely looking at my work. He said, "You are being too soft while brushing. This will not remove the dirt. You have to be a little harder, but not too much. If you are too hard, you will brush away the ICs. Just be as hard so that the black spots go away. You got it?"

I realized that he was actually right. I started to be soft while brushing on the ICs, but harder while brushing on the other areas on the motherboard. Then I started looking for black spots and trying to remove those. The whole point of servicing now became clear to me."

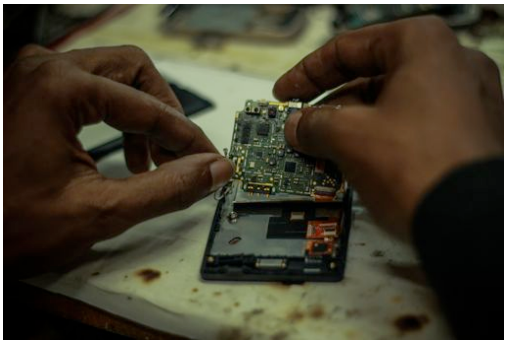

Figure 2: A repairer at Eastern Plus Market fixing a motherboard.

This example demonstrates that the appropriate level of "hardness" is hard to convey through explicit instructions; rather an apprentice has to learn that through his

experience. This sort of tacit knowledge is essential in repair work. The repairers get the inspirations for gaining these fine expertises from their passion for improving the quality of their work. Getting the task done quickly and making the repaired device visually attractive often bear the sign of skills of the repairers. Rupam once said,

"*The way I fix the mobile phone, it is hard to tell for others that the phone is repaired. But sometimes I get many phones where the repairers made the board look really bad, and you wont want to work on that. Some people just do not care to learn good work."*

Social Knowledge

Repair knowledge is not limited to technicalities. Rather, a repairer is educated on a lot of rules inside and outside the workshop: when to open and close the shop, when to take lunch, how to talk with the clients, when to turn the lights on, and when to clean the floor – these all are the examples of the social knowledge involved in the learning process of a repairer. Essentially, these teach an apprentice the values the repairer community holds.

A big part of knowledge in repairing is comprised of the lessons on how to deal with the customers, and fix the service charge. The following texts taken from the field note written during the apprenticeship at Rupam's workshop demonstrate how social knowledge becomes a part of learning in repair works.

"An old guy just came to our shop. He was looking for a battery that we do not sell. Rupam gently suggested that guy to get the appropriate shop to get the battery. But that old guy asked Rupam to get the battery for him. To my surprise, Mr. left the shop and got the battery for him. As the guy left, I asked Rupam why he had done so. Rupam explained, "*He is my old customer. I have to do this for him. This is how you keep your relationship with others in the community.*""

The practice of situated learning is also prevalent among bhangaris. Bhangaris need to know the social skills to keep good relationships both with the expert repairers and their customers. Jahangir, while explaining the reason behind his success in bhangari profession, said to us:

"*I collect the e-wastes from the secretariat and cabinets. Those are the places where you will find a lot of things. But not everybody can go and get things there. You have to dress properly and talk smartly. I have a good relationship with all the people who work there. So, I make a good business at that place.*"

These social skills are learnt by bhangaris while working with their seniors. For example, Jahangir's younger cousin recently started working with him. He was dealing with a customer who had been an old friend of Jahangir. At one point, his cousin said something inappropriate to that person. Jahangir immediately reacted and apologized to that person. He turned to his cousin and said, "*You do not talk like this to an old friend. You have to value people in order to value your business.*"

Figure 3: Repairers at Gulistan Underground Market.

DISCUSSION

The above discussion reveals the nature of explicit, tacit, and social knowledges at play in the repair worlds of Dhaka, Bangladesh. We have described how explicit knowledge arrives at, flows through, and is sustained among repairers through people, manuals, and Internet resources, keeping repairers up to date with global changes in technology. We have pointed to how repairers build tacit knowledge through observation, imitation, and repetition. We have explored the craft-based nature of repair knowledges, and how these skills were acquired through observation, repetition, and passionate engagement. We have also shown how apprentices in repair communities are converted to skilled repairers through their assimilation and absorption of core social practices and values. Beyond the simple transfer or acquisition of skills and knowledges, it is this essential component that accounts for the production and reproduction of vocational identities and wider communities of practice in the repair worlds of contemporary Dhaka.

The act of repairing itself is not very easy either; rather it is painstaking and laborious. Many repairers in the Gulistan Underground Market reported that mobile phone repair work involves very fine eye-work, and a person cannot continue in hardware repair for more than 20 years without significant damage to sight and body. Working conditions in the market are hot, crowded, and noisy, with questionable air quality tied to the frequent use of glues, solder, and solvents coupled with generally poor ventilation. Economic livelihoods in the profession may also be precarious, including in recent years as new and cheaper handsets and growing competition in the sector drive down the prices that can be charged for repair. At the same time, repair workers face the challenge of continuously updating themselves to keep track of newer technologies and changing environments. For this reason, learning remains a central and ongoing challenge for repair workers, who must continuously build their skills and networks throughout their career. In a very real sense, learning is a survival skill.

These findings carry important implications for ICTD scholarship. At the most immediate level, our study draws attention to the struggle that repairers confront due to the design and documentation strategies of global IT producers. New handsets are often designed *not* to be taken apart and fixed, guarded by a combination of glues, non-standardized fasteners (proprietary screws, etc.), and design decisions that locate core elements in hard-to-access portions of the device. Documentation of new models is often spotty or hidden (outside of the proprietary channels of the 'brand' shops) raising the time and difficulty involved in engaging new models. Improved accessibility, repair documentation, and other 'design-for-repair' strategies could substantially change this situation (and would align naturally with the sustainability and emerging market commitments of global IT manufacturers).

Second, in many developing countries repair (and the forms of tacit, and social knowledge that support it) is often neglected and devalued in formal engineering education, routinely ignored in higher end universities and only partly addressed by the underfunded and low status polytechnic schools. National education policies may need to consider paying more attention to these areas to build stronger support infrastructures for technology use and consumption. Third, transnational collaboration and information sharing through online sources is often less accessible for low-literate repairers. Automatic translation, video demonstration, and Bangla-lanaguage forums for local repairers might enhance learning, collaboration and wider access to knowledge within this segment of the local repair community.

Beyond this immediate level, the forms of knowledge, learning, and collaboration described in the paper reveal two parallel yet opposite realities with important implications for how we think about, design for, and practice collaboration and learning in transnational and third-world computing environments. On one hand, there is a structured network of knowledge present in Dhaka that connects local repair knowledges and practices with global hubs of learning and activity. People trained abroad bring their knowledge to the country and disseminate through teaching. The contents and methods of their teaching often reflect the foreign mechanisms of repair education. Also, the repairers often gather knowledge from Internet, and books written abroad. Knowledge that flows through this network from global knowledge hubs to the local repair community, attempts to align the local repair knowledge and practices with their global counterparts. This process points towards the ongoing role of global sources in shaping and supporting (or failing to) practices of technical learning and collaboration in developing countries, and the transnational politics of access, support, and dependency that may be central and often ignored features of ICTD [6].

On the other hand, local trainers and senior repairers make a significant effort to situate and adapt foreign knowledge to the exigencies of the Bangladeshi context. They invent metaphors and find alternative techniques to address the high cost of tools, unavailability of materials, associated monetary risks, and other social, economic, and infrastructural factors related to repair work. Through long processes of apprenticeship, repairers learn from existing practitioners how to translate and adapt foreign knowledge to local needs, values, and contexts. This part of the story reveals the collaborative effort to protect and enhance local cultures of technical skill and knowledge. In this way, top-down forces of global knowledge and bottom-up forces of localization combine to continuously reshape and update the terrain of repair learning and collaboration in Dhaka, and in many other developing sites. Now, the interplay between these two ongoing forces can be explained through postcolonial computing terms [5], and can be seen as a local resistance against foreign intrusion of technology, knowledge, and culture. This tension essentially calls for local IT and foreign policies that should consider the balance between these two sides based on national interest. This tension connects ICTD interests with the international politics through repairing works, and demonstrates how national foreign policies and transnational collaboration are instrumental in sustainable development through technology – an issue yet to be developed in ICTD research.

The biographies and descriptions of collaboration and learning above make it clear that tacit knowledge and master-apprentice relations sit at the center of learning to fix. These in turn depend on wider social relations of trust, standing, and respect. To make the learning process successful, an expert repairer is required to maintain a social standing and image that commands the respect of his apprentices. Similarly, apprentices must uphold a social standard and image to maintain the support of their masters. As described by both Polanyi [15,16] and Lave and Wenger [12], the transmission of tacit and social knowledges through observation, imitation and enculturation depends on trust, care, and respect. Hence, person's social skills are essential in developing the technical skills for repairing. Furthermore, our study also demonstrated 'internal' practices and valuations of quality of work that went well beyond what was required to satisfy or indeed would even be visible or recognizable to customers. Repairers took great pride in the quality of their work and recognized (or criticized) such qualities in others, features that align well with Sennet's [22] analysis of craftsmanship. Important parts of the apprenticeship and learning process were in fact dedicated to inculcating and reproducing this value in others. The social value of repairers is often threatened by the competition with 'engineers', and many repairers left their job because of the lack of proper recognition. By strengthening the standing and reputational economy of repair work, recognition of the craft-based quality and values of repair work could therefore improve sustainability and reinforce dedications to quality and reliability in repair

practice. These all suggest ICTD research to focus on building sustainable local social infrastructure to make technology sustainable.

Another important takeaway of this study is that the social landscape of repair is not purely collaborative and smooth, and this often inspires technology invention. Apprenticeships are not easy to get and never free of cost in Dhaka. Rupam's story revealed how difficult it was to get a job in a workshop even as an apprentice. Apprenticeship in repair shops is often organized through familial lines, or financial contracts. Also, apprenticeship is mostly practiced among the men, resulting into almost no presence of women in repairing market. Thus the flow of knowledge is sometimes strategic, transactional, and selective. Being cut off from such flows can push repairers towards experimentation, innovation and discovery, or to frustration, stasis, and decline. Even within the confines of the apprentice relation, knowledge may be jealousy guarded. In some cases, apprentices are held in extended positions of dependency and exploitation, performing large volumes of work at low levels of compensation. The repairers need to develop different social skills to survive in these challenging conditions. These examples demonstrate how inventions occur in challenged conditions of repair world in developing countries.

CONCLUSION

In this paper, we have shown the central and sometimes contested roles of knowledge, collaboration and learning in the worlds of mobile phone repair in Dhaka, Bangladesh. This study demonstrates the creative, social, and challenging nature of repairing and positions this as a prospective source of technical innovation in future. At the same time, this paper provides with important design and policy implications that can improve the repairing infrastructure of a developing country. In a broader sense, this paper calls for more attention to strengthen the repair and maintenance side of developing countries that have been significantly understudied within ICTD scholarship to date.

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