Learning, Innovation, and Sustainability among Mobile Phone Repairers in Dhaka, Bangladesh

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ABSTRACT
Acts of technology maintenance and repair constitute important and often overlooked moments in the operation of complex interactive systems. They also provide fresh insight on a series of problems – innovation, learning, and sustainability – long core to HCI concern. This paper builds on original ethnographic fieldwork in the repair markets of Dhaka, Bangladesh to advance three basic arguments: first, that repair activities in such locations reveal novel and significant forms of craft-based knowledge and innovation; second, that repair work is embedded in local and transnational flows that connect local practices to global networks and institutions; and third, that taking repair work seriously can cast new light on problems of learning and sustainability in the design and operation of complex interactive systems. We conclude with observations that relate our repair-based findings back to problems in interactive systems research and design.

Author Keywords
Repair; Design; Sustainability; Ethnography; Bangladesh

ACM Classification Keywords
H.1.2. User/Machine Systems: Human factors.

INTRODUCTION

HCI and interactive systems researchers have had much to say about practices and problems of design and use in complex interactive systems, but they've had less to say about repair. In mainstream understandings of the field, design and use constitute the starting and often end point for interactive systems research. The field's interests in core social processes of innovation, learning, and sustainability have typically been framed within a space defined by these two poles. How can new forms of design support innovation, learning and sustainability in the HCI landscape? How can actions taken by users change the way we think about and practice learning, innovation and sustainability? But this nexus of design and use does not fully cover the space of theoretical and empirical interest around these questions, nor does it exhaust the ways in which human agents engage interactive tools and systems in the world.

This paper reconsiders such problems from the standpoint of repair: the myriad activities by which breakdowns are addressed, function is restored, and longevity is extended in complex interactive systems. While there are broader theoretical and sociological dimensions to this question [6,15], our interest here is primarily material and technical in nature. How *literally* are broken objects fixed and restored, and what lessons for learning, innovation and sustainability might we derive from such experiences?

The rest of this paper offers empirical and analytic reflection on these questions, drawing on original ethnographic fieldwork with mobile phone repair workers in Dhaka, Bangladesh. We open by reviewing HCI literatures on sustainability, learning, and innovation in which problems of maintenance and repair figure centrally. We then turn to methods and findings from our fieldwork, including description of three exemplary techniques – "servicing," "jumpering," and "re-balling" – widely practiced among the repair workers we studied. We build on these descriptions to consider the distinctive forms of innovation that repair work embeds, and three central dimensions of the repair work we studied: repair as craftwork, repair as collaboration, and repair as creative repurposing. We conclude with observations that relate our repair-based findings back to more general problems in interactive systems research and design.

BACKGROUND AND LITERATURE REVIEW

Our research builds on a growing body of HCI and social science work around the practice, problems, and possibilities of repair. On one hand, this connects to a growing HCI literature around the nature and challenge of sustainability, both *of* and *through* the tools and infrastructures we study, use, and build. At the same time, recent work in repair has roots in much older traditions of HCI work, some of which have shaped fundamental understandings of the nature and limits of interactive systems themselves.

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DIS '14, June 21 – 25 2014, Vancouver, BC, Canada
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ACM 978-1-4503-2902-6/14/06…$15.00.
http://dx.doi.org/10.1145/2598510.2598576

Recent sustainability-themed research in the field has included efforts to rethink design in a more modular and durable direction, encouraging choices that support maintenance and repurposing over decisions to discard and replace [1]. Other work has developed tools and systems to support awareness and monitoring around things like energy and resource consumption, encouraging individual level behavioral changes that may reduce collective environmental footprints [5,19,29]. Still other work has pointed to the limits of such systems, noting how the behavioral assumptions underpinning them may misrecognize the highly systemic nature of many sustainability challenges, including groundings in historical, institutional, and infrastructural conditions that run 'above' and 'below' the level of individual choice and use [3,4,21]. Separate lines of work in collapse [31] and crisis [28] informatics have turned the sustainability problematic on its head, exploring the contributions of interactive systems and tools to contexts in which core social and technical infrastructures break down, and seeking to build resilience through design efforts that take the fragility of our systems and infrastructures seriously.

A broadly shared sensibility informs a growing body of HCI work on the nature, function, and consequences of repair, as practiced across a range of social and geographic locations. Rosner and Taylor [24] for example have looked to the craft-based practices of book restoration for insight into the neglected forms of work that may sustain and uphold technologies in the world. More recent studies [23,24,25] have explored practices and motivations behind the growing 'fixer' movements in North America and Europe, and their connection to wider cultural (and counter-cultural) movements. Recent work by Jackson and Kang [12] has extended this analysis to practices of technology repair and reuse among interactive and new media artists, drawing on post-humanist theories to connect moments of technical breakdown and repurposing to wider HCI concerns around creativity, innovation, and design.

Other work has extended these analyses in a transnational direction. Jackson et. al. [13,14] draw on ethnographic work in the Kavango region of northeastern Namibia to explore the relationship (and frequent disconnect) between local repair practices and more formalized programs of action associated with IT production and development programs. They emphasize the ecological organization of repair, pointing to the embedding of local repair activities in larger networks or 'worlds' through which flows of skill, resources, and material artifacts are managed. A similarly integrative sense characterizes Lara Houston's work on mobile phone repair operations in Kampala, Uganda, emphasizing both local forms of collaboration and invention and the transnational connections that tie local repair practices to global networks of production, value, and exchange.[9]

Such recent insights build in turn on classic traditions of HCI work with long theoretical roots in ethnomethodology, symbolic interactionism, and other social science traditions. Suchman's celebrated *Plans and Situated Actions* [30], for example, uses the experience of Xerox repair workers to codify a seminal distinction between idealized forms of action reducible to a plan, and the necessary forms of mess and contingency, breakdown and recuperation, that confront situated action in the world. Orr [20] extends this analysis, arguing for the creative and improvisational character of technical repair work, and the central role of non-codified channels – informal accounts, anecdotes, and "war stories" – in sharing repair knowledge. Theories of infrastructure advanced by scholars such as Star [27] and Bowker [2] assign a similarly central role to moments of breakdown and repair, noting the tendency of functioning infrastructure to "remain invisible until breakdown" – at which point awareness, attention, and the work of restoration kicks in.

In its modes of material engagement, the repair practices studied here also share properties with a growing body of HCI and interactive systems work around making, hacking, and other forms of DIY (Do It Yourself) work [16,17,25]. Like the maker movement and older traditions of work in participatory design [26], attention to repair challenges the traditional producer-consumer model, multiplying the forms and points of engagement by which technology is shaped (and reshaped) by actors beyond the sphere of professional design. Also like making and participatory design, repair emphasizes a highly tactile and creative relation to technical artifacts, pointing to forms of innovation and learning to be found in concrete and substantially craft-based engagements with a world of material things. In contrast to these movements, the turn to repair focuses our attention 'downstream' in this process, emphasizing how creative material engagements remain a part of our ongoing relationship with things in the world – and in fact are central to the ongoing coherence and usability of artifacts in the world wherever those relationships are to be maintained.

As this older and newer work makes clear, acts of repair constitute central but often overlooked moments in the lives and functions of interactive systems, producing many of the values – durability, stability, sustainability – that we look to interactive systems to provide. Repair work itself may entail elements of skill, innovation, and discretionary judgment that differ from forms of technical action and appropriation in HCI's better-studied moments of design and use. Repair work is also always situated within wider networks or ecologies of practice. And because of these differences, the forms of learning that support the transmission of repair skill and knowledge may differ from the channels through which the codified and schematic knowledges associated with design may flow.

The paper that follows tests and extends these claims, building on more than eight months of ethnographic

fieldwork in Dhaka, Bangladesh. This included a preliminary phase of 58 interviews, in which basic outlines of local repair practices were established, research interests and questions were refined, and contact with potential long-term informants was established; and two more substantive phases of ethnographic fieldwork, one conducted over 12 weeks between June and September 2013, and a second conducted over 5 weeks beginning in December 2013. This substantive phase of fieldwork produced more than 63 interviews and 70 discrete cases of individual fixing activities at 10 different repair sites. Our informants ranged from repair technicians, engineers, and apprentices to customers, owners and employees of local repair businesses. Interviews were supplemented by extended periods of participant observation, including periods of formal apprenticeship at two separate repair operations: one a private and semi-formal repair training center, and the other a stand-alone repair shop in a major downtown market. Interviews and field interactions were conducted in Bangla, and later partially translated and transcribed into English. This process produced a large quantity of textual and audio-visual data, including several hundred pages of fieldnotes and transcript data, more than 1000 photos, and a series of 10 videos in which common repair techniques were recorded.

The empirical description and analysis that follows builds on this fieldwork to explore three basic questions. What forms of innovation and learning are attached to the notably craft-based forms of IT repair in contemporary Dhaka? How are these activities situated and sustained within wider flows of knowledge, skill and resources? And how can such practices help us think differently about problems of innovation, learning, and sustainability in the design and operation of interactive systems more generally?

ECOLOGIES OF REPAIR IN DHAKA

Repair work and workers in contemporary Bangladesh operate within complex ecologies of practice organized across a spectrum of activities. At the formal end of this spectrum stand the 'brand' repair services offered by companies like Nokia, Maximus, and Symphony. These operations tend to hire repairers with technical degrees from local polytechnic institutes or low-ranked private universities. The forms of repair practiced here are circumscribed by company guidelines and rules, and are often limited to fixes of common problems under warranty. Our fieldwork suggests that brand repairers are also prone to replace rather than repair malfunctioning parts, and are less likely to engage in some of the more exploratory and innovative forms of repair described later in this paper.

A much larger percentage of local IT users are connected to repair shops owned and operated by single repairers or small groups of repairers in the informal or semi-formal sector. These shops operate independently, sometimes grouped together in larger clusters as with the "Gulistan Underground Market", and sometimes standing alone in larger and more general commercial locations. Users come to these shops with their broken mobile phones, and describe for repairers the problems they are facing. Upon gathering the stories and inspecting the phone, repairers either offer a fix for a servicing charge, or refuse. These repairers accept and work on a wide array of phones and brands, and in most cases do not have high institutional credentials. They may or may not have a very developed engineering sense of the design and function of the devices they work on. Their skills and expertise have been mostly acquired through practice and apprenticeship.

Some of these informal repair operations in turn got their start through training centers established by more experienced repair technicians, some with international connections. (The center one of the authors apprenticed at for example was established by a Bangladeshi national who previously worked for multinational telecommunications firms in Thailand and the Middle East.) Training centers are also well connected to importers of repair tools and parts, and often run a sideline reselling such items to other local businesses. They also function as a source of advice and guidance within the wider community, and as occasional specialists on particularly critical or complicated fixes.

Alongside these three classes of repair operations runs another community integrally connected to the repair of broken electronics. The "bhangari" (from the Bangla word "bhanga," meaning broken) circulate through repair shops and markets collecting materials (broken screens, faulty boards, etc.) that individual repairers no longer want. Some of these may be resold to other repairers looking for specific parts. Others may be sold in bulk alongside other kinds of materials (paper, plastics, etc.) that the bhangari also collect and redistribute as they circulate through the city. The single largest customer for their bulk sales are groups of Chinese businessmen, who it is rumored then export the materials for melting and precious metal recovery in China.

As this last description makes clear, beyond their human actors and networks, the forms of repair we studied are constituted in and through a complex space of material flows: of the phones themselves (broken and working) but also the parts, tools, and raw materials required to fix and maintain them. Reflecting current political economic realities in the region, many of these chains begin or end in China. Common equipment in the shops we studied included hot air guns, soldering irons, forceps, multimeter testers, and magnifying glasses, all of which can be purchased new, refurbished, or second-hand in the secondary markets located near important centers of repair activity. Repairers we spoke to estimated the total cost of purchasing these tools at around 100,000 BD Taka (approx. $1,285) though this could be reduced by purchasing second hand or refurbished equipment.

Local repair activities are also engaged in broader sets of international networks and flows. The vast majority of

mobile phones in use in Bangladesh today are designed, developed, and assembled outside the country. So are key accessories like spare batteries, chargers, replacement screens, etc. The tools and circuits that repairers work with are also made in other countries, purchased in most instances by importers who buy them on the Chinese wholesale market. Similar patterns characterize the flow of repair knowledge, which, like the materials themselves, often originate from countries of design and origin: for example, in the paper and online manuals that local fixers often use and sometimes jealously protect. Repair workers in our study often browsed the Internet from their phone or computer to find guidelines on how to fix new problems and devices; circuit diagrams were cited as particularly helpful resources (in part because they could be accessed apart from barriers of language and literacy that Dhaka repair workers sometimes faced). Some fixers checked the online GSM Forum every day in search of tips and insights from a global network of fixers.

In the sections that follow we return to these practices and flows from the standpoint of three more general features of contemporary mobile repair work in Bangladesh: repair as craftwork, repair as creative repurposing, and repair as collaboration. We begin however with three common repair techniques we witnessed.

Repair techniques: "servicing"

Our first example concerns the practice of "servicing," a repair technique known and practiced by virtually all the repairers in our study. In its specific usage here, servicing refers to a technique for washing and cleaning the motherboard, restoring functions lost through the intrusion of dirt or moisture. The note below describes one such servicing operation performed by Mr. R, the owner of a small repair shop in a downtown Dhaka shopping mall.

Figure 1: steps of servicing (clockwise, from top-left): opening the back-cover, putting thinner on brush, brushing the motherboard, blowing hot air.

On the day we are observing, a customer brings in a mobile phone with the complaint that the display is no longer working. Mr. R. chats with the customer, gathering history and background on the problem. After several minutes of bargaining a price is arrived at and Mr. R. agrees to takes on the repair.

Mr. R. begins by removing the back cover of the phone. He takes out the battery, then uses a small screw driver to remove the interior portion of the case. The small green motherboard is now visible. Mr. R. inspects the board carefully, checking each component for visible breaks or damage. Then he opens his desk and takes out a paintbrush and a small plastic bottle of thinner oil. Mr. R tilts the bottle to apply oil to the brush, then starts gently brushing the surface of the motherboard. As he works, he explains,

"*This is servicing. This is the first thing you should do with a mobile phone if it is not working. Look, I am cleaning the surface of the motherboard. If there is any dirt on the board that is creating the problem, that should go away now. When you start working as an apprentice, this is the first thing you will do. … In 70 to 80 percent cases, you can fix the mobile phone just by servicing.*"

After a few minutes, Mr. R puts down the toothbrush and switches on the hot air gun, adjusting the heat and force. He starts blowing hot air on the board, explaining that

"*Some ICs stop working and the hot air fixes those. Also, it will dry the board. The board became wet as I brushed thinner on it, as you just saw. Blowing the air is not very easy. You have to select a proper level of heat. Otherwise you will melt the ICs. Also, you cannot blow the air very strongly. That will blow the ICs from the motherboard and you will not get those back. This task looks easy, but it needs mastery.*"

Mr. R explains why servicing is necessary,

"*In our country, there is lots of dust everywhere. People who go out a lot expose their mobile phone to air and the mobile phones attract dust. The dust can enter into the case and sometimes affect the chips on the motherboard. Then the phones stop working. This is the most common case. The chips stop working due to humidity, too. They become damp. But if you apply thinner on it, and then blow hot air, they start working again*."

Mr. R is now done with the drying process. He returns the battery and cover to their proper places and turns on the phone. The display appears, and so does a smile on Mr. R's face. "*See? This is working now*," he tells us.

Repair techniques: "jumpering"

Our second case involves the practice of "jumpering," a common but challenging technique through which copper wire is melted onto the board in order to bypass (or 'jump') faulty elements in the circuit. The following note describes this practice as encountered one day at the Gulistan Underground Market.

One of the sets has an audio problem. Mr. A takes the set, opens the back cover and separates the motherboard from the body. As he does so, he explains to us,

"See brother, the problem is in the audio section. I know the portions and pins that work with audio. At first I'll try to investigate where the problem is with my naked eye. Most of the time, the problem occurs because of a disconnection on one of the lines. If I cannot identify the disconnection with my eyes then I get help from this meter. I check every connection with the multi-meter and if a faulty line comes along, you will see, there will be no reading."

Seeing no obvious breaks, Mr. A starts checking the connections. This is detailed and painstaking work. There are many connections on the board and they are very close together. Mr. R has to be very careful about where the ends of the probes are. His hands remain fixed; only the fingers are moving. He keeps checking, moving across the board until finally a broken connection is found. He says,

"You see, there is no reading in the multi-meter. That means this line is disconnected. When this kind of disconnection occurs, we need to jumper it."

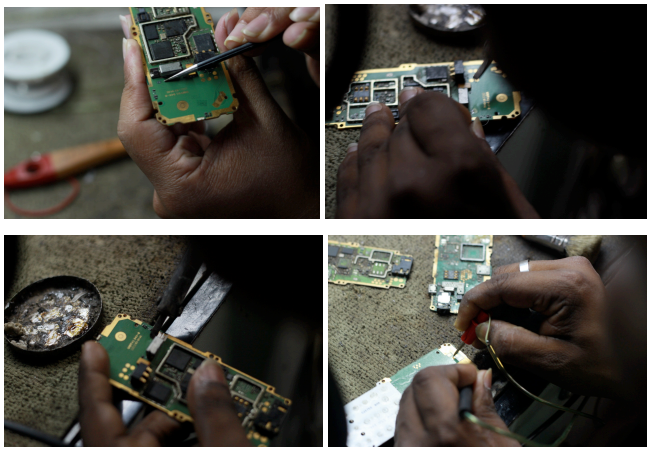

Figure 2: Steps of jumpering (clockwise, from top-left): Showing the broken audio connection, Reconnecting two points with a piece of wire, Melting wire with soldering iron, Rechecking the connection.

Mr. R then starts the jumpering process. He begins by placing octane on a brush and brushing the points of the broken connection. He then takes a thin piece of copper wire, which he cuts into smaller pieces. He picks up the soldering iron and runs it along the length of the wire. He explains that this will eliminate rust and impurities that may damage the connection.

He places the end of the wire at one of the connection points on the broken circuit, then carefully melts it onto the board using the soldering iron. This is exacting and delicate work. As he explains to us

"See brother, you need to be very careful when you do this. You can see there are other connection points around and it's so small. If you are careless, you may short other connections or you may connect other points instead of the desired point. That could ruin the entire board. You also need to be careful while selecting the wire. If the wire is not thin enough it may short other points."

He then takes the other end of the wire and connects it to the circuit in the same way. When the connection is complete, he brushes the points again and checks the new circuit he has made with his multi-meter. The indicator moves and he smiles. *"See brother, here you can see the reading. That means the connection is okay now."*

He places the board back in its casing and closes the back cover. He starts the mobile phone, opens the mp3 player, and selects a song. Music flows from the speakers.

Repair techniques: "re-balling"

Our third example concerns a process known locally as "re-balling," which refers to the practice of re-making missing pins within integrated circuits. This is considered a more advanced technique, and not every repair shop will take it on. The following note describes the re-balling process:

Mr. J has been mentioned by several of our informants as one of the most skilled repairers in the Gulistan Underground Market. He often provides advice and guidance to other repairers facing difficult or unfamiliar problems. Other repair shops also refer customers and more advanced jobs to him.

When we first arrive at his shop, Mr. J is bent over a circuit lying on his workbench, lost in concentration. After a few moments he looks up, smiles, and rises to shake our hands. At the same moment, a repairer from a nearby shop comes by and shows him a phone with a network connectivity problem that he is struggling to fix. Mr. J takes the phone and a multi-meter, and begins checking the circuits. He discovers the problem in the network IC – an automatic discard decision for most of the repairers we've observed to date. We ask Mr. J if he will replace the circuit with one from another board. *"No," he tells us. "Most of the time I try to repair the IC. If I cannot, then I replace it."* With the help of the hot air gun and a pair of forceps, he removes the IC from the motherboard, brushes it with octane, and places it under the lamp on his workbench. After a minute he points and says,

"Look at the corner of the IC. You can use the magnifying glass if you need to. See, there is a missing ball there. That's why it is not working. Every repairer cannot re-ball it. The work needs much concentration and skill. You will see why later. Even after re-balling, the IC might be completely damaged or the missing ball might not be re-created if you are not skilled enough."

He then takes a molding net, the most important tool in the re-balling process. The net has different patterns of tiny holes that correspond to the pin locations for different ICs. Mr. J explains,

"See, you will find different patterns for different models in this net. At first, you need to find the IC model that you need to re-ball in the net. After you identify the right model, you have to place the IC very carefully in the appropriate pattern."

Figure 3: Steps of Reballing (clockwise, from top-left): Placing IC on the net, Applying liquid metal to fill up the ball gaps, Applying soldering paste and hot air to melt and place metal nicely on the IC, Cleaning the IC .

He then takes the IC and very carefully places it on the net, double and triple checking the fit. Then he takes a bottle filled with what looks like liquid metal. He takes some on his finger, and fills in the pattern where he has placed the IC. Taking the net in his left hand, he switches on the hot air gun, waits for it to reach the appropriate temperature, and starts blowing hot air over the liquid metal. As he does so, he explains,

"This hot air will fix the metal permanently in the IC. You need to do it slowly and carefully. You have to understand how much hot air to use and how long to use it."

After about a minute he stops, and with the help of a cutting tool, carefully removes the IC from the net. He checks the IC to see if any balls now appear to be missing. Finding none, he washes it again and places the IC under the table lamp. He opens a bottle of soldering paste, takes some on a knife, and places it above the balls. He explains that the paste will help the balls set correctly in the holes, ensuring a solid fit. He once again applies hot air, the soldering paste melts, and the balls are soon seated correctly. Mr. J cleans the IC once more, returns it to its place on the motherboard, and reassembles the other parts. He replaces the battery, switches on the phone, and the network indicator lights up.

DISCUSSION: REPAIR AS CRAFTWORK, COLLABORATION, AND CREATIVE REPURPOSING

The techniques above provide entry into the distinctive forms of work, skill, and innovation that constitute contemporary repair work in Dhaka. Repairers in places like the Gulistan Underground Market engage complex problems attached to the function and sustainability of sensitive, sophisticated and fast changing technologies. Their expertise is painstakingly acquired through years of observation, apprenticeship, practice and experiment. Success in this environment depends on skills and knowledge acquired and developed over long periods of time, and on complex collaborative networks in the local and global environments. As one senior repairer summarized for us,

"*It takes a lot to be a good repairer. You have to have a passion for technology. You always have to update yourself with the latest changes in the technology. You have to learn quickly, and practice. You have to be experimental, and you have to keep a lot of things in your mind. Being a good repairer is not child's play*."

These features reveal distinct qualities of creativity, collaboration and learning that we believe mark IT repair as an innovative form of human-computer interaction, an under-recognized profession, and a distinct technological vocation[11]. In the discussion that follows, we identify three more general features or dimensions of this work: repair as craftwork, repair as collaboration, and repair as creative repurposing.

Repair as Craftwork

As the above examples show, mobile phone repair as practiced in the shops and markets of Dhaka constitutes an exacting and highly skilled practice, with a high premium on experience, dexterity and material manipulation. A repairer requires sharp eyes, efficient hands, and a perfect co-ordination between the two developed over years of attentive observation and rigorous practice. This goes well beyond any abstract or conceptual knowledge of technology (indeed, repairers in our study were ambivalent about how much conceptual knowledge was actually required to do their job) and rests substantially on the diagnostic judgment, situated knowledge, and embodied skill of the repairer – properties variously described to us under the languages of passion, feel, or heart. As Mr. A, who has been teaching repair for more than 12 years, describes it:

"*I can only teach you what to do in which situation. At best, I can show you how I do that myself. But I can never teach you how you will do that when you need to. This is why two students in my same class do not become repairers of the same expertise, no matter how I try. There is an instinct, a passion, a way of tuning yourself with the rhythm of the work, and a way of understanding the tools and techniques with your heart – that's what makes you a good repairer. You can become a scholar merely with your knowledge, but to become a good repairer you need to be a performer*."

Saying so, Mr. A brings out two motherboards on which students in the previous training session had practiced 'jumpering'. One is neatly done, and shows few signs of having been fixed at all. The other shows burn spots, extra wires, and signs of other damage.. Mr. A continues,

"*See, both of them are my students and both come from similar backgrounds. It is true that both of them did 'jumpering', and both boards are working now. But just by looking at these two boards, you know who has learnt repairing, and who has not. This is where the repairers need to have skills beyond their technical knowledge*."

Another repairer described for us his six-month process of learning how to properly hold and adjust the hot air gun. Pointing to his workbench, he says,

"*Each of these tools requires months of hard work, patience, attention, and practice to learn how to use, … and then years of experiences to learn how to use for solving a particular problem a customer brings you. If you make even a little mess, you will spoil everything. These are very delicate devices. You have to learn and be very careful even about how much thinner or soldering paste you apply on the board, and how much heat and air you are blowing, where exactly your iron is touching, etc. This may look easy from the outside, but only a repairer knows how much it takes to bring a broken device back to a functioning state."*

Repair as Creative Repurposing

The repairers in our study also demonstrate noteworthy skill and creativity in their repurposing of broken and discarded parts given to them by customers, other users, or purchased from bhangaris. Upon encountering a part that cannot be fixed, their first move is to try to replace it with items taken from the stock of broken phones and components in their collection. As one repairer explained,

"*A mobile phone is never useless altogether. You can use its parts. You can use the display; you can use the ICs of the motherboard. If nothing works, you can at least sell it to the Bhangaris."*

Given the range of phone models out there, this work often goes beyond simple replacement to constitute acts of creative and improvisational repurposing, making available parts work well enough for the purpose at hand.

Other forms of creative repurposing surround the improvisational use of tools. As described above, heat is commonly used to remove or restore connections between ICs and the motherboard. The most common device for this is the hot air gun. Mr. A however teaches his students how they can achieve the same effect using the heat of a 60 watt light bulb – a creative workaround to the expense, bulk, and occasional unavailability of the heat gun. We found similar creative substitutions for soldering paste, thinner, soldering irons, and several other tools and materials commonly used in repair shops.

Different but no less skillful examples of creative repurposing can be found among the bhangaris. By sorting and redirecting the flows of broken and partially functioning devices (some on to recyclers, some back to other fixers) bhangaris play a crucial role in the material flows and networks by which repair activity in Dhaka is accomplished. This work too requires talent, skill, and creativity — to select and buy the right devices at the right price, to cultivate an appropriate network of buyers and sellers, and to see such objects through to their final destination, whether by recirculating them into other repair activities or on to Chinese recyclers for disposal.

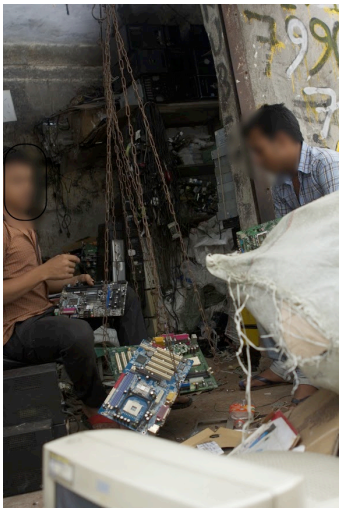

Figure 4: A young bhangari weighing motherboards on a scale.

Repair as Collaboration

Repairers often collaborate with each other while fixing mobile phone sets. New phone models change constantly, challenging any individual repairer to keep up. Skills and experience are also distributed unevenly throughout the community, and fixers may become known for their work on particular techniques, devices, or problems. Few repairers can fix all the problems that come their way, but they rarely refuse customers. Instead they'll take the order, and then get help from their friends, colleagues, or senior fixers in the community to solve the problems. In some instances, whole repairs may be outsourced to other fixers.. This practice is particularly common among fixers outside of Dhaka, who may lack the skills and resources to deal with all of the issues they encounter. Such repairers traveled periodically to the capital to consult or bring orders to the more skilled technicians and shops in our study. For example, Mr. K was a previous student of Mr. Ro, and now operates a repair shop in Dohar, a 2 hour drive from Dhaka. He comes to Mr. Ro once a week with mobile phones that he cannot repair by himself. Mr. Ro takes and fixes the phones, which Mr. K. returns to their original users, splitting the servicing charge between them.

Such networks of help, collaboration, and support are the primary means of acquiring knowledge in the repair world. Many of them are organized through apprentice forms and relations like the one sketched above. One senior repairer recounted for us how he got started in repair as a teenager, by standing beside the repair shops in stadium market and

watching them work. He would also help by bringing tea if they requested it. As he explained to us,

"*If you keep on standing before a shop, at some point people will start noticing you. At first they will ignore you. But when they will see you standing everyday there, they will ask you, "what are you up to?" That is the time you have to offer your help to them… The same thing happened to me. At first I would help them by handing the tools or bringing the tea, and I would watch what they do. I would ask them questions while they were repairing. Slowly I became able to help them in a better way by doing the 'servicing' part for them. They also started to give me some money for my work. This is how it started."*

Beyond such local resources, repairers often draw on advice from the Internet when they struggle to deal with unfamiliar problems or devices. Mr. R, a senior but low-literate repairer, shows us how he uses his mobile phone to search for information over the Internet. On the browser of his mobile phone, he goes to google and then types "*Nokia 6170 mic problem solution.*" A list of results shows up with a strip of corresponding images, most of them are diagrams of motherboards. Mr. R says, *"I check the images. Sometimes you will find some Youtube videos, too."* He then clicks on an image and the corresponding page appears. After looking at the diagram for some time, he says, "*See, this is the connection. It starts from here and ends there. Now I will check the same in the board. If the connection is OK, and the IC is OK then the function of the mike is OK."* Mr. R returns to the phone he is working on in search of the connection revealed in the image.

Literate repairers in our study were regular readers and occasional contributors to "GSM Forum", an online site where technicians from around the world share tips and advice around new models, techniques, and particularly challenging repair problems. One, Mr. A., also manages an online Bangla-language blog, where he writes about different repair techniques. He reports that he receives questions and compliments not only from repairers inside the country, but also from overseas Bangladeshis as far away as the Middle East, USA, and Canada.

The importance of these networks of collaboration, learning, and support should not disguise the fact that IT repair in both its local and global dimensions is also an intensely competitive space, marked by rivalry, limited resources, and proprietary interests. Particular techniques and knowledges (including resources like paper manuals, specialized tools, and engineering diagrams) may be jealously guarded. Some repairers in our study preferred not to take on apprentices or share their experience, for fear of future competition. Others were happy to take on referred work from other repairers, but would not allow them to observe the techniques being performed, out of fear that such sharing would undermine the likelihood of being asked to perform such work again in future. As explored in greater detail by Houston [9], similar patterns characterize the spread of reputation and knowledge through global venues like the GSM Forum. It is this delicate balance between sharing and competition, openness and closure, that accounts for the overall structure and practice of repair collaboration in Dhaka today.

CONCLUSION

The above descriptions provide insight into the distinctive forms of craft, collaboration and creative repurposing that mark contemporary IT repair activities in Dhaka. These share many features with forms of thought and action identified several decades ago by Claude Levi-Strauss [18] as "bricolage," referring to the borrowing, assembly and creative repurposing of existing knowledge and resources to solve individual and collective problems. In Levi-Strauss' original, the term is used to mark a distinction between "mythological" styles of thought and the more structured forms of reasoning best exemplified in the goals-means logic of western engineering. Most subsequent scholars building on Levi-Strauss – including those seeking to apply these concepts to acts of technological making and design – have rejected this broad cultural claim, pointing instead to the presence of bricolage at the heart of the very 'western' forms of practice and knowledge that Levi-Strauss was seeking to mark as separate [8,32].

We share this latter inclination. The forms of innovation to be found in the repair workshops of contemporary Bangladesh are best positioned not as alternatives to engineering knowledges but as necessary but forgotten *extensions* of them, points of connection and completion through which the abstract design of manufactured goods are made real and sustainable in the world. The repairers in our study exhibit rare forms of talent in diagnosing problems in sophisticated electronic devices, often piecing these together from the accounts of malfunction offered by their owners. They apply forms of technical mastery and creative problem solving acquired through long experience and perseverance. Through the creative repurposing and restoration of broken devices, repairers provide critical and very often invisible [2] infrastructure that underwrites and sustains the 'mobile revolution' in places like Bangladesh.

Repair work also exhibits distinct and noteworthy forms of learning and collaboration. The basic and most prevalent of these concerned apprenticeship. Early career repairers learn while observing and helping senior technicians in their work, graduating form menial tasks (fetching tea, organizing tools, etc.) to low-level fixes, to more complex operations with increasing premiums on knowledge, skill, and judgment. The same progression marks hierarchies of professional prestige and respect, with more esteemed members set apart by the care and skill of their work. While abstract conceptual knowledges hold a disputed place in the community – different repairers we spoke with provided different answers as to how important such knowledges were – the embodied skill of master fixers was held to be indisputable, as was the need for slow and careful mastery

of basic manual functions: exactly where and how long to hold the heat gun, the well-soldered connection, etc. As long traditions of work in tacit and craft-based knowledge have shown [22], many of these core skills defy abstract description, and are understood and taught as matters of touch, feel, and art. They also underlie the deep vocational values that mark and sustain fixing as a way of life [11].

Through all of these activities, repair workers in Dhaka make central contributions to HCI and environmental goals of sustainability. The creative repurposing done by repairers (and the similarly skilled work of the bhangari) helps ensure that devices are maximally used; and when broken beyond repair, that their parts are recirculated into other uses and devices. Such activities extend and complete the material cycle of technology, reducing the amount of waste left to burden the environment. In all these ways, repair contributes to local and global projects of sustainability.

Such contributions should not, however, mask the real-world challenges and difficulties that repair work and repair workers face. Repairers work at the downstream end of a fast-moving industry, and must keep up with a constant barrage of new phone and motherboard designs, often with limited resources and access to information. Strain on bodies and eyes may be severe, challenging long-term sustainability of the livelihood. Such problems may be exacerbated by the hot, crowded, and hazardous conditions prevailing in locations like the Gulistan Underground Market, where significant repair activities are conducted below grade and without adequate ventilation. Besides such physical limitations, income in the industry is variable and subject to disruption, including through periods of strikes, blockades, and political unrest (as held true through substantial periods of our fieldwork in 2013).

In recent years repair workers have been additionally squeezed by the threat of increasing competition as more workers enter the industry and a growing influx of cheap Chinese handsets, which are undercutting the prices repairers, can charge. As one repairer explained,

"*Who will now come to us to fix a set that costs 1200 Taka [~$15US]? And how much should we demand for our repair work? But the complexity of the problem that we fix remains the same both for the 1200 Taka set and the 50,000 Taka [~650US] set.*"

Beyond such difficulties, the repair workers in our study suffered from basic challenges of social standing and recognition. As one senior repair worker explained to us,

"*Young guys are coming to this repair profession, because they can easily get some money here. But there is no recognition. People call them 'technician', not an 'engineer'. If they called them 'engineer', they would feel a lot better. They can do things far better than many engineers around.*"

When asked if they would want their children to follow in their footsteps, most informants offered some variant of the below response:

"*No, I want my son to be an engineer, or a banker, or anything he likes. Not a repairer! There is a lot of work here with little income. And people do not recognize us.*"

The accounts above have attempted to shed light on sites of HCI practice and actors – namely, repair and repairers – that have been systematically understudied in HCI and interactive systems research to date. They've done so in a type of environment (the repair markets of Bangladesh) that has been similarly neglected in HCI work (though growing bodies of work in post-colonial computing [10], and 'computing at the margins' [7] have begun to address this hole). HCI has had much to say about design and designers, and increasingly around use and users. But it's had less to say about fixing, and even less about fixers in places like Dhaka. This is a problem because it leaves large parts of the wider HCI universe unexplored, open spaces on the 'map' of real-world computing practices that we are slowly assembling.

But it's also a problem for the holes it leaves in our understandings of questions already near and dear to the heart of the field. This paper has explored the distinctive forms of craft-based innovation to be found in the repair markets of Dhaka. It has considered the forms of collaboration and learning that structure flows of knowledge, skill and experience in the broader repair worlds of Dhaka, including their important linkages to local and transnational networks. And it has called attention to repair as an important focus for the growing body of HCI work around global problems of sustainability. If HCI research is to produce better answers to these and other questions, it may need to pay more careful attention to sites and moments of repair like those practiced in contemporary Bangladesh.

ACKNOWLEDGEMENTS

Research for this paper was supported by funding provided under the Intel Science and Technology Center for Social Computing.

REFERENCES

1. Blevis, E. Sustainable interaction design: invention & disposal, renewal & reuse. In *Proc. CHI 2007*, ACM Press (2007), 503–512.
2. Bowker, G.C. and Star, S.L. *Sorting things out: Classification and its consequences*. MIT press, 1999.
3. Brynjarsdottir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., and Sengers, P. Sustainably unpersuaded: how persuasion narrows our vision of sustainability. In *Proc. CHI 2012*, ACM Press (2012), 947–956.

4. DiSalvo, C., Sengers, P., and Brynjarsdottir, H. Mapping the landscape of sustainable HCI. In *Proc. CHI 2010*, ACM Press (2010), 1975–1984.
5. Froehlich, J., Findlater, L., and Landay, J. The design of eco-feedback technology. In *Proc. CHI 2010*, ACM Press (2010), 1999–2008.
6. Graham, S. and Thrift, N. Out of Order: Understanding Repair and Maintenance. *Theory, Culture, Society 24*, 3 (2007), 1–25.
7. Grinter, R.E., Best, M., Edwards, W.K., and Mynatt, E.E. *Computing at the Margins*. Unpublished NSF workshop report available at http://computing-margins.org/workshop.pdf.
8. Harel, I.E. and Papert, S.E. *Constructionism*. Ablex Publishing, 1991.
9. Houston, L. Inventive Infrastructure: An Exploration of Mobile Phone. *PhD Thesis, Department of Sociology, Lancaster University,* 2014.
10. Irani, L., Vertesi, J., Dourish, P., Philip, K., and Grinter, R.E. Postcolonial computing: a lens on design and development. In *Proc. CHI 2010*, ACM Press (2010), 1311–1320.
11. Jackson, S.J. and Barbrow, S. Infrastructure and vocation: field, calling and computation in ecology. *Proceedings of the* In *Proc. CHI 2013*, ACM (2013), 2873–2882.
12. Jackson, S.J. and Kang, L. Breakdown, Obsolescence, and Reuse: HCI and the Art of Repair. In *Proc. CHI 2014*, ACM Press (2014), Forthcoming.
13. Jackson, S.J., Pompe, A., and Krieshok, G. Things fall apart: maintenance, repair, and technology for education initiatives in rural Namibia. In *Proc. iConference 2011*, 83–90.
14. Jackson, S.J., Pompe, A., and Krieshok, G. Repair worlds: maintenance, repair, and ICT for development in rural Namibia. In *Proc. CSCW 2012*, ACM (2012), 107–116.
15. Jackson, S.J. Rethinking Repair. In T. Gillespie, P. Boczkowski and K. Foot, eds., *Media Meets Technology: Essays on Communication, Materiality and Society*. MIT Press, 2013.
16. Kolko, B., Hope, A., Sattler, B., MacCorkle, K., and Sirjani, B. Hackademia: building functional rather than accredited engineers. In *Proc.* 12th Participatory Design Conference: Research Papers-Volume 1, ACM (2012), 129–138.
17. Kuznetsov, S. and Paulos, E. Rise of the expert amateur: DIY projects, communities, and cultures. In *Proc.* 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, ACM (2010), 295–304.
18. Lévi-Strauss, C. *La pensée sauvage*. Plon, Paris, 1962.
19. Mankoff, J.C., Blevis, E., Borning, A., et al. Environmental sustainability and interaction. In *Proc. CHI 2007*, ACM Press (2007), 2121–2124.
20. Orr, J. *Talking about machines: An ethnography of a modern job*. Cornell University Press, 1996.
21. Pierce, J., Fan, C., Lomas, D., Marcu, G., and Paulos, E. Some consideration on the (in)effectiveness of residential energy feedback systems. In *Proc. DIS 2010*, ACM Press (2010), 244–247.
22. Polanyi, M. *The Tacit Dimension*. Doubleday & Company, Inc., 1967.
23. Rosner, D.K. and Ames, M.G. Designing for Repair? Infrastructures and Materialities of Breakdown. In *Proc. CSCW 2014*, ACM Press (2014), Forthcoming.
24. Rosner, D.K. and Taylor, A.S. Antiquarian answers: book restoration as a resource for design. In *Proc. CHI 2011*, ACM Press (2011), 2665–2668.
25. Rosner, D.K. Making Citizens, Reassembling Devices: On Gender and the Development of Contemporary Public Sites of Repair in Northern California. *Public Culture 26*, 1 72 (2014), 51–77.
26. Spinuzzi, C. The methodology of participatory design. *Technical Communication 52*, (2005), 163–174.
27. Star, S.L. and Ruhleder, K. Steps Towards an Ecology of Infrastructure: Complex Problems in Design and Access forLarge-Scale Collaborative Systems. In *Proc. CSCW 1994*, ACM Press (1994), 253–264.
28. Starbird, K. and Palen, L. Working and sustaining the virtual Disaster Desk. In *Proc. CSCW 2013*, ACM Press (2013), 491–502.
29. Strengers, Y.A. Designing eco-feedback systems for everyday life. In *Proc. CHI 2011*, ACM Press (2011), 2135–2144.
30. Suchman, L. *Human-machine reconfigurations: Plans and situated actions*. Cambridge University Press, 2007.
31. Tomlinson, B., Silberman, M., Patterson, D., Pan, Y., and Blevis, E. Collapse informatics: Augmenting the sustainability & ICT4D discourse in HCI. In *Proc. CHI 2012*, ACM Press (2012), 655–664.
32. Turkle, S. *Life on the Screen*. Simon and Schuster, 2011.