Technology Maintenance: A New Frame for Studying Poverty and Marginalization

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ABSTRACT
This paper offers a new theoretical frame for those interested in poverty and design. As digital access rates peak, *technology maintenance* argues that the digital divide will increasingly manifest in the (in)ability to stay connected. As a novel and conservative test, open-ended data from a 748-person university student survey of technology maintenance were analyzed. Use and ownership were ubiquitous, but students demonstrated variability in *coping with the inevitable*; disconnection was more burdensome for low-resourced students. Findings extend technology maintenance and are leveraged as a starting point for three calls for action in HCI: 1) the CHI community should research the burdens of poverty in poor *and* wealthy contexts; 2) new HCI projects should accommodate inconsistent access; and, 3) new design choices should minimize disruption and optimize stability. This requires action at the individual and organizational level as designers create products that consider marginalization but also use expertise to influence policy.

Author Keywords
Digital divide; poverty; technology maintenance; access

ACM Classification Keywords
H.1.2 User/Machine Systems

INTRODUCTION
The digital design community has long been interested in human welfare [e.g. 9], as exemplified by robust bodies of scholarship on design for disability, global development, and environmental sustainability. However there are notable gaps in the literature on design and socio-economic marginalization within wealthy countries, though recent scholarship may signal a change in this regard [15, 23]. Aims to broaden the scope of prosocial HCI research may thus be aided by the application of a new theoretical lens.

Technology maintenance argues that, as the divide in access and use closes, the digital divide will manifest as the inability for low-income and marginalized groups to *maintain* access [10, 11]. Maintaining access for the poor is complicated by reliance on technology that is more likely to be broken, shared, and *dependably unstable:* cycling through regular periods of disconnection (e.g. prepay cell phones that are regularly without minutes [12]). Maintenance involves constant upkeep of financial, technical, and relational resources, such as balancing phone and gas bills when money is tight or maintaining social ties that can loan a back-up phone. These phenomena are especially insidious in wealthy countries where representative data gives the appearance of widespread ownership and use [e.g. 27]. A handful of studies at CHI and elsewhere have found evidence of chronic 'underconnectedness' in the US [28, 29, 41], but have not yet used a theoretical frame to explore the issue.

A shift in the digital divide poses new challenges for policy makers and new opportunities for technologists and designers. This paper situates this new frame within existing HCI research by leveraging unexplored qualitative findings from the first quantitative survey of technology maintenance in a socio-economically varied population: university students. After evidencing indicators of often overlooked disparities, I then pose three calls to action to designers interested in social change. My aim is to channel prosocial efforts that have focused on non-Western poverty and environmental concerns to think about sustainable HCI from the perspective of economic justice worldwide.

HCI and poverty
There is a long tradition of relevant research on poverty and digital technology in poor countries (i.e. ICTD). Mobile technologies in particular have been embraced for addressing problems like rural economic development, e.g. [26], health promotion [8], and democratic political involvement [37]. Although some projects show more promise than others [4], this work reflects the design community's commitment to improving quality-of-life in non-Western contexts. Along the way researchers have urged restraint from pushing Western agendas onto people with less money and darker skin [15, 17, 23]. This 'post-colonial' approach is more culturally sensitive and may better optimize design success and scalability [2, 4, 17, 39].

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There is also a small but important body of extant research at the intersection of digital technology and poverty in wealthy countries. Examples include location-based systems to support food assistance programs [7], or the role of banking and employment technologies for the unemployed [21, 35]. There is also work on digital media use by the homeless, and organizations that serve the homeless [23, 24]. This work has done a good job of recognizing that successful intervention should move "*toward* a sustainable *process* of developing and refining attachments to different socio-technical resources and *away* from focusing simply on co-creating a temporally and materially fixed *artifact* (italics his)" [23, p.1352]. In other words, access to digital technology is not a permanent or categorical state but rather an ongoing experience of labor, negotiation, and coping. These findings are echoed in the handful of HCI studies that explore how low-income and racial minorities in the US struggle with access [29, 41]. Technology maintenance may facilitate new projects for those interested in poverty, especially in places where initial access is achieved but maintenance is a continuous struggle.

Theoretical contextualization

Technology maintenance research originated from interviews with public housing residents in the US [10]. Although those low-income residents ostensibly *had* cellphones, their access mirrored the disruptions described by residents in poorer countries. One key difference between maintenance problems in wealthy and poor countries, however, is that institutions in wealthy countries (e.g. schools, work, government services) expect reliable communication with most residents. Subsequent studies have found that, because the majority of low-income US Americans no longer have a landline telephone [3], disrupted cellphone access disrupts communication with healthcare providers, employers, and much needed personally supportive ties [11, 12]. Low-income US Americans overwhelmingly report technology ownership and Internet use, but are often unable to pay monthly bills and own slow, broken, or shared devices [28]. In other words, because those in the US are increasingly expected to have ICT access, frequent disruptions or 'underconnection' may have serious yet underappreciated consequences, potentially exacerbating inequalities [34, 36].

The idea that digital access is now about maintenance speaks to existing theoretical constructs in HCI. For example, work on *infrastructure* assumes that digital technology is more than a bounded device or system, but rather an amalgam of resources, including stable access to electricity, education, political stability, personal health, community participation, etc. [2, 31]. Another related concept, *obsolescence,* highlights the fragility of digital technology and the patterns of casual waste that we have come to expect in a global society [33]. This literature is often motivated by concerns for environmental costs, but rarely addresses the human cost when people struggle to maintain access; a technology maintenance lens refocuses this phenomenon on economic justice. Finally, research on repair and reuse proposes an epistemological opportunity for rethinking the "crude functionalism of the technology field" by acknowledging and investigating moments of digital breakdown [18, 19, 20]. Like technology maintenance, this work builds on scholarship in anthropology and philosophy that stresses the importance of repair as necessary, inevitable, and political [13]. However, most of this work in HCI has focused on middle-class repair in wealthy countries [e.g. 30], and repair by the poor in poorer countries [e.g. 1, 39]. Technology maintenance also appreciates the struggles of poor communities in wealthy societies as an opportunity for broadening ideas of and solutions for digital instability.

A conservative test

Previous research on technology maintenance has explored disconnection low-income adult populations, primarily as it influences health [10, 12]. But Hargittai [14] notes that assumptions about universal access for young adults makes the consequences of disconnection for youth particularly pernicious. A more stringent test of technology maintenance, then, is to examine maintenance problems in a younger *and* more socio-economically diverse sample where use and ownership are likely to be pervasive. Evidence of technology maintenance phenomena within this sample would broaden the framework to a new, education context and better demonstrate its breadth. I thus ask: how does socio-economic status affect students' abilities to stay connected and the consequences of disconnection?

METHODS AND ANALYTIC APPROACH

Students from a large midwestern university participated in a survey for credit over three semesters between 2014-2015 mostly from a 350-person course on social media. The final sample included 748 students, 51% were self-reported female, 46% freshman and 73% were White. These data were collected as the first quantitative operationalization of previous qualitative findings [10, 11, 12]. As part of the study, survey participants were also asked open-ended questions about whether "problems with technology (e.g. broken, inaccessible, malfunctioning software or hardware)" had ever affected students' ability to "complete coursework on time" or "caused problems in personal relationships." Although the data here are modest in scope they provide a window into an aspect of technology maintenance that is important for student quality of life and may shape social inequality. Quantitative findings are being reviewed elsewhere, but these findings offer important insights on student experiences in their own words.

Of students surveyed, 359 students described having problems with late assignments and 124 students had problems in relationships because of technology disruption. Responses were sorted using a standardized index of socio-economic status (SES): mother's education (6-item scale),

father's education (6-item scale), and parent tuition support (3-item scale), (M = .005, SD = .76; $Med.$ = .16). As education and income are common metrics of SES, parent tuition support is used as a proxy for income (α = .63). Using techniques common to sociological analysis of qualitative interviews, such as grounded theory, open-ended responses were then critically read and analyzed to detect common themes across participants and between low and high-SES using a median split [5, 6]. Supplemental notes were analyzed, with the final analysis focused on summarizing core themes and identifying disconfirming evidence that suggests that low-SES and high-SES students have different technology maintenance experiences. A dominant theme emerged that further builds on the technology maintenance lens, and is explored below.

RESULTS

Coping with the inevitable

Across SES, problems with laptops and the internet frequently affected students' ability to complete assignments on time. However, low-SES students had more ongoing problems and greater difficulty regaining access. In other words, *coping with the inevitable,* was the theme that emerged across respondents, but in very different forms.

Temporarily disrupted internet and printer access in particular was an equalizer across SES: students of all SES noted loosing access in the middle of completing or submitting an assignment. One student noted: "*literally while attempting to answer this question I lost internet connection using [campus wi-fi].*" Many reported stress (e.g. "*panic and run to the library," "I cried, and then I used someone else's computer…")* and, as one middle-SES student noted, some received lower grades:

"when I lived at my parents house freshman year I occasionally turned assignments in late because of trouble with the internet (too slow, not connecting, etc). I couldn't really do anything about it; I just had to accept a lower grade."

Computer crashes were the other frequent cause of late-assignments. Computer crashes occurred for low and high-SES students, and students in both groups often turned to a friend or campus-resources when problems arose. Low-SES students (26ppl), however, had difficulty regaining stable personal access than high-SES students (11ppl). To illustrate, a high-SES student noted:

"during finals week last semester my Apple computer would not turn on so I had to take it into the store. Thankfully, I had insurance and it was fixable; however, it was a rough week. I had to borrow my friend's laptop or basically live in a computer lab on campus to study and get my work done. My apple computer was fixed within a few days."

In contrast, a lower-SES student wrote, *"over the summer my laptop broke down and I couldn't get it fixed until after summer classes ended."* Temporary problems were universal, but reconnection was harder for lower-SES students, and, as the previous student went on to note, "*set my coursework back*." Low-SES students were also more likely to report persistent problems:

"my computer is rather trashy because it came without any protection on it and got a virus the very first day I got it. It sometimes works and then randomly on some days will just not go to websites and stays loading a page for hours so I go to the computer lab in my dorm."

This example of technology maintenance underscores the fact that ownership does not ensure access, which is a never-ending process rather than a categorical state, even for university students. More importantly, disparities in reliable connections may exacerbate social inequalities if low-income students have a harder time completing assignments, which could affect long-term academic success and future job prospects.

As with schoolwork, there were also reports of relationship stress because of technology problems, in this case, phone or Skype disconnection and poor cell service. Again, students faced similar problems across SES, but the source of these problems differed (e.g. remote vacation location v. lack of money), as did the solutions. Some high-SES students used back-up technologies when access was compromised (11 ppl). As one high-SES student wrote,

"I spent the summer somewhere where the internet access was very low and there was no cell phone service…I would call my family once a week from a landline and talk to my friends and family using Facebook chat…Overall, it was actually nice to 'unplug'."

Low-SES students were less likely to reference alternative communication when personal communication was disrupted (7ppl). For example, one low-SES student wrote:

"broken phones and technology get costly very fast. I broke a smartphone one time by accident and didn't have a replacement while I was at IU, and my mom at home couldn't help until I came back home. Then it became very costly to fix the problem, and this is difficult when there are other things to pay for. The problems with broken technology get solved, but those problems come with a bigger price not everyone is able to pay."

As this poignant quote conveys, both high and low-SES students were ultimately able to maintain digital access, but low-SES students often pay a higher price for maintenance because additional resources were limited and extenuating circumstances (e.g. illness, foreclosure) complicated solutions. Thus, the core finding from the first analysis of technology maintenance in a socio-economically diverse sample is that SES informs students' ability to *cope with the inevitable*, the consequences of which touch facets of both academic and personal life.

DISCUSSION

These data posed a more stringent test of technology maintenance, previously only examined in low-SES adult

samples. Findings reveal that even some of the most connected individuals worldwide—US college students—cannot consistently depend on technology. Moreover, those with fewer resources have a more difficult time regaining access and, for them, the costs of disconnection may be greater. This work elaborates on technology maintenance research describing low-SES citizens in wealthy countries slipping through the cracks of wired social and political institutions (i.e. healthcare, employment, education, etc.) [10, 11, 12]. Findings that students must *cope with the inevitable,* offer a glimpse into disparities even within a hyper-connected segment of the global population. Although disheartening, this transition from disparities in use and ownership to disparities in access maintenance provides new opportunities for designers. Following are three calls to action for those interested in mitigating this evolving digital divide.

Design to understand disruption

First, I echo previous scholars that call for more HCI work on the poor and other marginalized groups within the US and other wealthy countries [15, 41]. Of course, studies on socio-political marginalization from across the globe are important. But we should ask ourselves: why do HCI scholars study poverty in other parts of the world and not the poverty that abounds in the wealthy countries most of us call home? Why are we uncomfortable or uninterested in economic inequality around us? There is a lot of room to build on the small extant body of investigative studies [e.g. 29, 41] and HCI interventions [e.g. 7, 21] that aim to reduce the suffering and experience of poverty and marginalization closer to home. The HCI community should ask questions that bring attention to and mitigate the consequences of poverty in those contexts as well.

Design to accommodate disruption

Second, HCI researchers should accommodate disruption in the plethora of design and evaluation studies taking place. This is especially true when designing for the poor and marginalized, but research on any new system should account for inevitable disruption and maintenance. As the results above indicate, nearly all people experience short-term disruption. How effective can a new doctor-patient portal be if the sickest patients own computers too slow to use? What happens when a new-student welcome app is inaccessible to the lowest-SES students? As Yardi et al. point out, "HCI should attend to socioeconomic factors like race, income and education of its users…otherwise it risks conflating study results with socioeconomic factors" [41, p.3049].

Studies that have successfully done this have found that the need to share devices in communities of color limits the reach of educational computing resources [29, 41]. In Nairobi, the need to conserve expensive phone minutes prompted recommendations of more prominent display of remaining airtime and rethinking services that put callers 'on hold' [39]. But these studies are the exception rather than the rule. If technologists design without accounting for and accommodating disruption, further embedding technology into daily life will only amplify existing disparities [25, 34].

Design to reduce disruption

Finally, technologists are in a position to reduce disruption with hardware and software design. These recommendations have been made before, often with a focus on the environment [16, 19, 22], but in most cases sustainable design would also serve the poor by minimizing costs. This includes investing in modular design of mobile and laptop parts that can be replaced without purchase of an entirely new device [16, 22], or making those devices repairable by using non-soldering techniques (http://www.verdantelectronics.com/). Users might also benefit from promotion of secondary IT markets for selling, sharing and repair—a specialized 'Craigslist' that allows technicians, consumers, and vendors to interface—thus sustaining the life of second-hand devices. Campaigns to inform non-profits about how to help clients sustain access might also be useful (e.g. pbdd.org). These are just some of the ways that those in HCI can design to help reduce disrupted access. Much more work here is needed as well.

CONCLUSION AND POLICY IMPLICATIONS

This paper introduces a new frame to the HCI community and elaborates on previous technology maintenance findings. There is much to learn from extant research, especially in sustainable HCI and HCI4D, that can mitigate the costs of unstable access. Technology maintenance can facilitate that investigation, especially as disparities in maintenance widen over coming decades.

As access rates of computer and mobile use plateau in wealthy countries, the HCI community is in an extraordinary position. Although innovation may always amplify social inequality [34], we are at a point in history, as ICT policy becomes fixed, to decide who can fully take advantage of groundbreaking digital innovations and who must make due with systems that are out-dated, costly, impossible or illegal to repair, and dependably unstable. Researchers who care about poverty and marginalization must therefore get involved at multiple levels of 'infrustructure' design. This includes leveraging technical expertise to collaborate and share best practices with organizations that serve the poor (e.g. nten.org). It could also involve lobbying governments to institute policies that promote access to marginalized users (i.e. see recent FCC proposals to subsidize broadband access), and coming up with incentives for ICT corporations to optimize product longevity. As Suchman [32] wrote, "innovation and change are inevitably costly undertakings, and require associated commitments to their ongoing, long-term development." Over the next decade the need for this commitment from the HCI will only come further into relief.

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