Designing for Repair? Infrastructures and Materialities of Breakdown

Daniela K. Rosner
Department of Human-Centered Design and Engineering, University of Washington
dkrosner@uw.edu

Morgan G. Ames
Center for Social Computing, Department of Informatics, UC Irvine
repair@morganya.org

ABSTRACT
This paper explores issues that come up in practices of breakage and repair through two projects: the "XO" laptops of One Laptop Per Child in Paraguay and public sites of facilitated repair in California, USA. Collectively drawing on 15 months of ethnographic fieldwork, 156 interviews, and archival research, we find that breakdown and repair are not processes that designers can effectively script ahead of time; instead, they emerge in everyday practice. These practices are shaped by material, infrastructural, gendered, political, and socioeconomic factors – such as manufacturing limitations, access to repair parts and expertise, and environmental convictions – which designers often did not, and may not have been able to, anticipate. We call the material realities and practices of repair *negotiated endurance*, which is illustrated by four themes from our findings: the negotiated identification of breakdown, collaborative definitions of worth, the fraught nature of collaborative expertise, and the gendered stakes of repair.

Author Keywords
Breakdown; design; infrastructure studies, maintenance; materiality; One Laptop Per Child; public sites of repair; repair; sociotechnical systems.

ACM Classification Keywords
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INTRODUCTION
Over the last ten years, repair-oriented design, engineering, and policy-making have begun to take hold at local and global levels. Recent legislation reforms such as the Right to Repair Bill (http://righttorepair.org), for example, require automobile manufacturers to provide the same repair instructions and diagnostic data to consumers as they do to franchised dealerships. Going one step further, a few companies have proactively built repairability into their products. Patagonia has produced a jacket with a repairable zipper, asking consumers to take on fixing work themselves. Other projects enable repair through customization, such as the IKEA hacking movement wherein the modularity of mass-manufactured IKEA furniture turns unassembled pieces into LEGO-like reconfigurable units [34] or the GreaseMonkey browser plug-in that enables substantive end-user modification using the open standards of the Web [31]. Decades earlier, the Volkswagen Beetle of the 1960s was hugely popular around the world and often hailed as a force of democratization in part because of its ease of repair and modification [33].

On the other hand, within IT production one dimension of design is "planned obsolescence": the manner in which a product is built to last for only a few years rather than a lifetime, and meant to be replaced, not repaired. The phrase "planned obsolescence" was popularized in 1932 by Bernard London in his pamphlet entitled "Ending the Depression through Planned Obsolescence" [22]. The concept is canonized today in technological observations-made-rules such as Moore's Law, with its short turnaround for the doubling of computational power. In keeping with either Moore's Law or London's exhortation, a number of computers, electronics, and smaller consumer appliances have been designed to fail over time and be replaced. For example, battery-operated electronic products, notably recent releases of Apple iPhones and Macbook laptops, come with difficult-to-replace bonded batteries, and heating devices like toasters, hair dryers, and electric hot water kettles have flimsy resistive heating elements that are cheap to produce but not made to last.

In this paper, we explore the theoretical and material dimensions of breakdown and repair practices in the 'wild,' attending to the points at which obsolescence is thwarted and repairability is not realized, and the social implications of both. In the process, we introduce the notion of *negotiated endurance*. This refers to the process by which different actors – including consumers, community organizers, and others – drive the ongoing use, maintenance, and repair of a given technology through the sociocultural and socioeconomic infrastructures they inhabit and produce. In this framework, breakdown and repair are not simply planned or avoided through design, but instead actively produced and reconfigured through use.

We illustrate our argument with two case studies. The first chronicles the unexpected breakdowns and repair work on the "XO" laptops of One Laptop Per Child (OLPC) in Paraguay. The second explores the repair activities of the Fixit Clinic, a space where the public can bring broken appliances which volunteers help them repair. In both case studies, we explore how users approach breakdown and repair to provide new theoretical and practical insights into the design process. This

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involves questioning not only design for reparability in particular but also design practices in general – after all, products are all repairable to varying degrees, and breakdown and repair are often part of use even if not of design. Those who are engaged in repair practices both acknowledge and complicate the politics of design, especially design that is meant to encourage or discourage repair.

One contribution of this work is to theorize breakdown and repair as material states that are defined collaboratively in use. Moreover, both are closely tied to collective definitions of worth – as in, what is worth repairing. Why are people repairing or *not* repairing, and what does repair mean to them? How are objects designated as in need of repair in the first place? Our case studies show that breakage and repair both have multiple meanings and create different practices and roles, all of which offer different models of use and creativity.

Another contribution is to highlight the political and infrastructural aspects of breakdown and repair. This builds on the work of Steve Jackson and others in this area [16,17,18,19,28,37], testing the ability of these theoretical contributions to travel to new political, economic, and social contexts, including technology democratization projects in the Global South (OLPC) and countercultural urban repair initiatives (Fixit Clinic). In this framing, repair is a political act, a repurposing of designed objects in ways that may or may not have been planned. Tools or facilities for repair are similarly political in that they can rewrite conventional beliefs about what we can change and how we can change it, or be an admission that breakdown has occurred. Finally, our case studies highlight how repair can be a *privileged* practice, relying on certain kinds of materials (replacement parts, testing equipment) and forms of expertise to be carried out.

Related Literature on Repair

Before we turn to our case studies, we wish to acknowledge the small but vibrant ethnographic tradition that has emerged around the study of everyday maintenance in IT design. Decades prior to this work, Lucy Suchman, Julian Orr, and colleagues turned to the lives of photocopy machine repair workers to illuminate the limitations of codifying maintenance techniques [28,38]. Orr's influential accounts of particular diagnoses exposed skilled service work as "necessarily improvised, at least in diagnosis, and centered on the creation and maintenance of control and understanding" [28:161]. Orr showed how repair workers not only use manuals and codified organizational knowledge; workers also rely on the retelling of "war stories" – personal accounts from the field often shared over lunch or informal meetings. Each repair activity involves situated actions whose intent, in Suchman's terms, "must be contingent on the circumstantial and interactional particulars of actual situations" [38].

Others have studied practices and conceptions of consumer electronics disassembly in developing countries, as examples of thwarting planned obsolescence. Burrell [4], for example, describes how e-waste scavengers in Ghana, who are "invisible users" not planned for in the design process, retrieve parts from mobile phones, computers, and other electronics in landfills to reuse components and precious metals. Jackson et al. [18] further explore what they term "repair worlds" in Sub-Saharan Africa to show how information technology infrastructures are routinely maintained and extended.

Studying repair in the Global North, some work in HCI on sustainability has explored designing to enable maintenance and repair in order to support environmental concerns ([2] provides an example and [11] a summary), which we will see echoed in the motivations of the Fixit Clinic below. From "IKEA hacks" that rely on shared resources, online and off [34], to traditional crafts that can be learned through online how-to instructions [39], the Internet has created new opportunities kludging and hacking. Applying repair beyond hardware, Kelty [20] has studied the arcana of free software through the continuously rewritten fabric of the Internet. Beyond IT development, scholars have focused on a range of maintenance work, reconsidering aspects of building reconstruction [3], vehicle repair [8,9,15,22], electricity procurement [14], book restoration [35], routine work activities [16], and shared infrastructures [37].

Following from these scholars, this paper aims to examine practices of design and repair through the material conditions and cultural contingencies they surface. Drawing on two case studies that provide in-depth examinations of repair activity, we explore the myriad avenues in which repair work interfaces with design, especially the difficulties in designing to specifically enable or disable repair. This account illustrates some of the many complications that can arise in practice.

Methods

The methods used in this study are largely qualitative and ethnographic but also include quantitative and archival elements. For the first case study, the second author conducted six months of ethnographic fieldwork in Paraguay in 2010 as a volunteer for Paraguay Educa, as well as archival research on One Laptop Per Child (OLPC) between 2008 and 2013. Paraguay Educa is a small non-governmental organization (that is, a group not affiliated with the Paraguayan government, with funding sources independent of government support), founded and run by local Paraguayans, which purchased OLPC laptops for around $200 each (near the cheapest price the laptop, and its non-tablet successors, ever reached [42]) with funding from the SWIFT banking group, the Inter-American Development Bank, Itaipú Dam, and other donors, and brought them to Paraguay in 2009. In 2010 the project consisted of 4000 laptops in 10 schools, and as of this writing includes 9000 laptops in 36 schools. The second author observed the effects of broken laptops in classrooms and at home during the course of field observations, and interviewed 133 participants in Paraguay, including children who had laptops that were broken to varying degrees or had been repaired. She iteratively coded her fieldnotes and interview transcripts to identify the dominant themes across all sources, one of which was breakage and repair, the data presented in this paper.

The second author complemented this ethnography with quantitative data to corroborate her findings. Of particular importance to this analysis, she obtained from Paraguay Educa complete logs of laptop breakage reports and repairs filed by the Paraguay Educa support staff, which were all recorded in a system custom-built by a Paraguay Educa developer. This data included types of breakage for each laptop in the program, allowing layering of additional levels of analysis including the laptop owner's gender (categorized by their name, before anonymization of the dataset), grade (provided in the database), and whether they lived in the urban center or the rural outskirts of their city (determined by their school).

The first author conducted nine months of participant observation at seven public sites of repair (six Fixit Clinics and one Repair Cafe) in 2012 and 2013. She engaged in informal conversations at those events with roughly 60 participants. She also conducted extensive formal interviews with 23 participants, including leaders and participants in four public sites of repair (Fixit Clinic, Palo Alto Repair Cafe, Pasadena Repair Cafe, Fixer's Collective, and the Netherlands Repair Cafe), and leaders of related endeavors such as the Repair Clinic, Pasadena Repair Cafe, and the Flaming Lotus Girls. Lastly, she conducted in-depth research in the Fixit Clinic and Repair Cafe's online archives and in individual participants' collections. She transcribed her interviews and iteratively coded her fieldnotes and transcripts to find emergent themes.

CASE STUDY 1. THE CONTESTED REPAIRABILITY OF OLPC LAPTOPS IN PARAGUAY

One Laptop Per Child (OLPC) represents one of the largest experiments in laptop-driven learning underway. About two and a half million of OLPC's "XO" laptops are in use around the world, 85% of them in Latin America. It has also inspired derivative projects in both education and low-cost computing. Among the project's promises were that the XO laptop would be rugged enough to withstand the roughness of child use and so easy to repair that a child could do it. In this section, we explore the social implications of laptop breakages in the field, noting the ways that actual breakage departed from the idealized breakage that OLPC envisioned. The results make painfully concrete the possible material limitations of designing for repairability and the material requirements of repairwork. We also explore the implications that the approach OLPC encourages projects to take – every child owning their own laptop and being responsible for keeping it in good repair – has for social equity, one of the project's goals.

Figure 1. OLPC's "XO" laptops in Paraguay, one decorated with stickers by its owner.

OLPC's Idealized Repair Practices

OLPC's XO laptop is the first of its kind to combine an allegedly ruggedized design, an open-source educational software suite, and full (if intentionally underpowered) computer functionality. The XO has no internal moving parts such as fans or a hard drive to jam or break when dropped; minimal connectors to get broken or dirty (just USB and audio, both covered by the XO's antennae "ears" when the laptop is latched, plus a power connector and SD slot); a solid silicone membrane keyboard to make the laptop water-resistant; a thick plastic case to protect it from falls or other wear and tear; and only two sizes of screws – with extras included inside the handle – intended to make dismantling and repairing the laptop easier (see http://wiki.laptop.org/go/Disassembly and http://wiki.laptop. org/ go/ Screws). OLPC leaders, including the project's founder Nicholas Negroponte, demonstrated the ruggedness of the laptop during talks and events by flinging one across a stage, then picking it up and turning it on, leading to expectations among those interested in implementing their project that the laptop was very difficult to break [5,43].

OLPC hoped that in addition to making the laptop robust to the use of children, these design features would encourage children to tinker with the laptop's hardware (along with its open-source software) – in short, to be their own tech support, understanding the machine inside and out. OLPC's first Core Principle, Child Ownership, encouraged locally-run projects to give laptops to children directly so that they could take the laptops home and learn anywhere and anytime, not just at school [27]. They also maintained that child ownership would encourage children to take better care of their laptops, and even empower them to repair the laptops themselves [26,30], providing an excellent learning experience and making them comfortable with 'hacking' the laptop. Because the laptop was ruggedized, they theorized, the repairs that would need to be made would never be too serious [41].

Though expecting children to repair their own laptops has been called naïve or exploitative by some critics, OLPC leadership Nicholas Negroponte, Seymour Papert, and others have defended it as the perfect learning experience, taking advantage of children's supposedly natural proficiency with technology and allowing them to delve as deeply as possible into the workings of the machine. In a USInfo "Webchat" interview about OLPC in 2006, Papert directly claimed that having children repair the laptops is a matter of empowerment, not exploitation:

I believe in "Kid Power." Our education system underestimates kids. It infantilizes them by assuming they are incompetent. An eight-year-old is capable of doing ninety percent of tech support and a twelve-year-old one hundred percent. And this is not exploiting the children; it is giving them a powerful learning experience. [30]

To assist these repair activities, OLPC developers and volunteers populated OLPC's wiki with technical details about the laptop, often including descriptions and even debates about what the feature being discussed was meant to accomplish (see http://wiki.laptop.org/go/Battery_and_power for an example). While initially and ostensibly meant for laptop users at any level of expertise, over time this documentation became more and more aimed at people with a high level of technical proficiency. This tendency accelerated after the "Give 1, Get 1" XO laptops reached the hands of tens of thousands of OLPC enthusiasts across the United States and Canada around Christmas 2007 and 2008, before many OLPC projects around the world – including the one in Paraguay – had begun. As a result, most of these resources, which were nearly all in English, were aimed more at other tech-savvy enthusiasts than at novice users.

Breakage in Practice: OLPC's XO Laptops in Paraguay

Paraguay Educa, the locally-run non-governmental organization (NGO) in charge of the project of 9000 XO laptops in Paraguay (4000 first-generation XOs distributed in spring 2009, 5000 second-generation XOs distributed in spring 2011), initially embraced the Core Principles and central tenets that OLPC had laid out as important [1], including child ownership and the ruggedness of the XO. As a result of OLPC's framing of the project, the NGO Paraguay Educa, as well as other projects including the country-wide, government-run project in Uruguay, did not stress the importance of being careful with the laptop or work to procure and stockpile repair parts. However, as we will see and as has also been described elsewhere [46], limitations in the XOs' manufacturing process and the ways that children used laptops in practice – and the problems that resulted from both – differed from OLPC's initial expectations of ruggedness and ease of repair, which they had passed on to many of the early projects.

For one, the prevalence of cement corners and bumpy cobblestone streets in Paraguay meant that dropped laptops often did *not* emerge unscathed – and screens were the most frequent casualty. While the screen would generally survive impacts to the bumpered *edges* of the laptop, as would most likely happen in a demonstration onstage, some falls resulted in a direct impact to the screen surface itself, to which it was not nearly as robust. After an impact, a screen would often either go entirely black, rendering the laptop unusable (with no hookups for external screens nor a supply of external screens available), or would sport a cluster of permanently dead pixels, making it more difficult to use. Similarly, nearly every smartphone encountered in Paraguay had a cracked screen; one Paraguay Educa staff member cracked his the very day he bought it, much to his heartbreak. Though these smartphones could be repaired, the cost was prohibitive for even the relatively wealthy members of the NGO.

The location of the camera above the screen (like most laptops) also meant that children who were taking pictures with their laptops would often walk around with their laptops open and screens rotated to face out. While taking pictures was not that common an activity overall, one breakage of a screen rotated in this way was observed during fieldwork. Other observations involved close calls, as children sprinted across schoolyards or down cobblestone streets holding an XO on one arm, often open to play music. In interviews, children without working laptops or with laptop screens that had been replaced described using their XO on their bunk bed and accidentally dropping it a meter and a half to the floor, or putting it on a shelf or on top of a wardrobe only to have it jostled off. One child explained in an interview that she lent her laptop to her younger brother, and it was returned with a screen that no longer turned on, and no way for the family to afford the repair part. Overall, as of August 2010, one year and four months into the project, 403 (10%) of the 4000 laptops in use had unfixed broken screens.

Another part that often did not stand up to children's use was the AC adaptor. Though there was much early press regarding alternative power sources for XO laptops, nearly all in use around the world are charged conventionally by plugging them in to a power outlet. Through what was described by Paraguay Educa and OLPC technical staff in the field as a manufacturing flaw, the rubber used to make the cable for the first generation XO's adapter was stretchier than it should have been which, when combined with some students' tendency to swing their adapters or pull the adapters out of the wall by the cord, resulted in breakages. Still others suffered from a design defect that burned out the adapter unit itself. All in all, in August 2010, 21% of laptops had at one point logged a problem with charging, and 12% had unfixed adapters.

While these two parts broke an order of magnitude more often than most others, they were not the only breakages, and moreover, these logged breakages were not the only problems with using the machines. For example, the membrane keyboard of the first-generation XO was made slightly too thin to withstand heavy use, and over time the membrane cracked at the edges of the most-used keys, inviting fidgety students to pick at them further or eventually falling off on their own. In August 2010, 3% were logged as broken. The trackpad on the first-generation XO was notoriously buggy and difficult to use (see http://wiki.laptop.org/go/XO-1/Touchpad/Issues) – not technically "broken" (in the sense that it was not functioning as designed) but still an impediment to use. Also frustrating to students and teachers both was the laptop's slowness and its much-too-small one-gigabyte solid-state hard drive, which would fill up quickly with students' Internet-enabled media-centric usage patterns. These issues came to be collectively understood and discussed under the framework of breakage, though not all had a clear path for repair.

Even more troubling, breakages tended to recreate gendered and socioeconomic divisions. While *software* problems were roughly equal, an August 2010 data sample noted that more boys had *hardware* problems than girls (with a ratio of just over 4 boys for every 3 girls), especially the kinds of hardware problems that resulted from rough handling, following Paraguayan gender norms similar to those in the United States that generally allow boys to be more rambunctious than girls. Similarly, three laptops belonging to rural students had hardware problems for every two belonging to urban students per capita, though software problem reports were roughly equal between the two groups. This was perhaps a result of longer walks home and more unsupervised time as parents worked late. The potential for the project to be a social leveling force was thus undermined by laptop breakage.

A few of the employees from the NGO Paraguay Educa and OLPC noted that such problems were likely the result of the tradeoff between using more easily-serviceable parts and cost-cutting, with the decision often falling on the side of cutting costs to approach as closely as possible the $100 target price for the laptop (though it wasn't able to get much below $190). This meant that some parts were in fact epoxied to the motherboard and were nearly impossible to service. In this way, the idealism that OLPC initially had for the laptop being easily repairable was tempered by limitations imposed by the laptop's manufacturers, who were not as committed to the ideals of open hardware.

In sum, though OLPC's hardware designers anticipated some potential problems, their early claims that the laptop was unbreakable and that children could do the necessary repairs, as well as limitations in manufacturing, led to a number of problems among projects using first-generation XOs. The much larger project in Uruguay reported similar results [9,10,32]. In fact, estimates of the number of inoperably broken laptops in Uruguay ranged from 25% to 35% despite the government's extensive investment in repair facilities and subsidization of repair parts [36:11]. Several of these problems were fixed in the second-generation XO, but that does not help those who received first-generation laptops (and the second-generation XOs had their own manufacturing problems, such as a wireless card that failed more frequently). Though many technologists may think nothing of upgrading their devices frequently, hundreds of thousands of first-generation XOs are in use by students around the world, with little hope or budget for an upgrade, even after the laptop's five-year expected lifespan.

Material Requirements of XO Repairability

With the exception of power adapters, none of these breakages resulted in repairs that children could do without a supply of replacement parts. However, compounding the problems caused by laptop breakage, Paraguay Educa, being a small non-governmental organization running a relatively small project by OLPC's early expectations, had difficulty procuring these parts. According to Paraguay Educa's technical staff, OLPC told the NGO in 2009 or 2010 that they simply do not sell repair parts, since OLPC was too small to handle the maintenance of projects themselves. As a workaround, Uruguay's much larger government-run program went directly to the manufacturers to buy a large number of spare XO parts, and sold the NGO Paraguay Educa small batches of them out of goodwill – though much of this supply, especially the parts that broke most often, was quickly exhausted. As a result, during this fieldwork, just over one quarter of Paraguay Educa's laptops had documented but unfixed hardware problems. Of the 1095 unfixed hardware problems in Paraguay Educa's inventory system in August 2010, one year and four months since laptops were distributed, 474 involved a broken charger, 403 a broken screen, 139 a broken keyboard or trackpad, and 79 other hardware issues.

Some of these breakages could be repaired without replacement parts. One could borrow a charger or splice its cables for a temporary fix, tape bits of paper over the missing keys on the keyboard, or buy an external mouse if one's family was wealthy enough – some mice were observed in use, especially in the more wealthy private schools. However, a broken screen was particularly problematic. It was not only common, but it also rendered one's laptop unusable until a replacement screen was available and one's family saved 303,600 guaranies (about $65) to buy one. Only the charger broke more often, and only the motherboard cost more to replace.

Even when repair parts were available, many were prohibitively expensive for many Paraguayan families. While the official minimum wage in Paraguay in the second half of 2010 was 1,507,484 guaranies (about $320) a month [44], minimum-wage laws were under-enforced [40] and the majority of the population worked either in the exempt public sector or in Paraguay's still-extensive informal economy [13], making significantly less than minimum wage. In particular, rural families, many of them subsistence farmers with side businesses selling home-grown or homemade products on the side of the road, were unlikely to be able to afford repair parts, even though the repair *labor*, supplied by the NGO Paraguay Educa's technical support team that rotated through all of the schools in the program every week, was free. As a result, aside from chargers – which, with the possibility of splicing, had roughly equal rates of repair in urban and rural schools – most hardware problems were repaired roughly twice as often in urban schools as in rural schools. Thus, though the laptop program did help lessen the socioeconomic urban-rural divide in Paraguay, in some ways, the divide persisted in both breakage and repair rates.

One obvious solution to problems of breakage is one of more resources: extra laptops for school use, a consistent source of repair parts, and perhaps money to subsidize the cost of parts in cases of financial need, much like Uruguay's project had – though even with these resources, Uruguay's reported breakage rates were also quite high. Lacking these resources – as a small non-governmental organization dependent on donations and, like many small NGOs, often on the brink of running out of funding – Paraguay Educa had to look to other solutions. One initiative that they began during this fieldwork used parts

from two broken laptops belonging to children in the same family (siblings or cousins) to make one working laptop that the children co-owned.

Other initiatives focused on changing the narrative from the one initially provided by OLPC – that laptops were rugged enough to even be thrown around – to one that emphasized their fragility and the responsibility of students or families in *preventing* breakage. During fieldwork in 2010, Paraguay Educa embarked on a campaign publicizing how to care for XO laptops, detailing under what conditions the laptops should be used (sitting down, the laptop resting on a solid surface, plugged in if possible), how to clean them, and how to do simple diagnostics. The NGO's trainers showed videos on the topic to students, and some teachers created and hung posters about how to care for XOs in their classrooms. The training sessions for teachers in the second phase of the project, who received second-generation XOs (with a 4GB hard drive and a better trackpad) in 2011, emphasized *not* OLPC's message about the ruggedness of the laptops but their fragility and the expense of repairs. While it was too early to assess the results of this campaign in 2010, of note here is that it departed from the story often told by OLPC and the press about the laptops to one based on what was happening to laptops on the ground. Along these lines, one of the more enthusiastic laptop users encountered during fieldwork was also one of the most fastidious and had independently concluded that the laptops needed to be cared for. She carefully swabbed her keypad and trackpad with an ethanol solution every day and exhorted her sixth-grade classmates to do the same.

Breakdown of laptops did lead to collaborative technology use – but not particularly the kind that OLPC, or students, really wanted. In the classroom, some teachers had students without working laptops pair up with those who did to do laptop work, but these students were often relegated to observation rather than active participation. Some children with broken laptops were able to borrow a laptop from a family member or (less commonly) a friend who rarely used theirs, though their use of the borrowed machine was generally more circumscribed than use of their own laptops would be, as the lender and borrower sought to balance memory usage, program installation or de-installation, and general care for the still-working machine. Moreover, since the lender had to reclaim their machine at least for classroom use and assignments, the borrower generally lacked the complete freedom with the borrowed machine that they would have with their own machine – or, in some cases, got the lender in trouble by deleting needed software or finished assignments. But more often, students with broken laptops just did not use a laptop anymore.

Practices of Repair in Paraguay

Though the leaders of OLPC hoped that children could do repairs themselves, almost all repairs were done by the NGO Paraguay Educa's teacher trainers or their technical support team, which consisted of two full-time staff members and a number of part-time volunteers from a local university. Some repairs, such as software re-installation, power cable splicing, and checking for loose connectors, could be done on-site at the schools, each of which the team visited once a week.

Some students and a few teachers took interest in these repairs, and the repair staff members were often surrounded by a cluster of students as they fixed laptops. A few teachers and students learned some basic diagnostics this way – one enterprising teacher offered a cable-splicing service for 5000 guaranies ($1), and one student made a point of getting the latest software from the repair staff and installing it himself on his friends' computers, though this often unfortunately overwrote all of their personal projects. Interestingly, most of the students who engaged with the repair staff were boys. Though several girls interviewed were just as interested in their laptops as the most interested boys, they had less interest in repair, labeling it as a "boy's activity," citing their shyness with the all-male repair staff, or saying they preferred to *prevent* breakage as reasons for not engaging. Even when female teacher trainers (or the author, also female) tried to engage them in repair, they were not interested.

Paraguay Educa's programming staff, which was quite skilled (even pushing software updates upstream to the official worldwide software distribution) and sometimes included international volunteers, also occasionally took on some repair and diagnostic work to discover software bugs to fix. They worked almost entirely at one particular school, taking about a day a week of one sixth-grade class to install new versions of the software and observe for bugs. The director of this school was the most outspoken in her support of the project, even incorporating it into her school's charter (and then trying to claim a greater share of scarce project resources in exchange). The international volunteer from OLPC who overlapped with several months of this fieldwork was even more proactive. He encouraged students, boys and girls alike (though girls were often shy with him), to learn to do basic hardware diagnostics – in effect running an informal repair clinic in the classroom, though in observations, such repair activities only happened hesitantly with his direct intervention and encouragement. He was moreover unique in this activity; other Paraguay Educa employees, while not avoiding students, also did not usually encourage them to become involved to that degree.

Almost all repairs that required a replacement part could not be done on-site, and required the repair staff to first wait for repair parts to be available (sometimes a long wait, as demand for some parts, especially screens and chargers, outstripped supply), and then to collect the cost of the part (sold at-cost to students) from the student's family – if they could afford it – before they could make the repair. After the cost was paid, they took the computer back to their office, did the repair, updated the software, and returned the computer to the child in a subsequent visit to their school. Sometimes long waits would lead to confusion and frustration on the part of students and teachers, who thought their laptops had been permanently confiscated when in reality they were just waiting for repair parts. And if families couldn't afford repair parts, as many rural families in particular could not, another site of socioeco-

nomic division would emerge as laptops were relegated to the backs of closets or tops of shelves, reduced to "bricks."

CASE STUDY 2. FIXIT CLINIC AND PUBLIC SITES OF FACILITATED REPAIR

We have seen the complications that can arise from breakage and in repairing products designed to be easily repaired. What of products not necessarily designed for repair, but embedded in worlds with ample resources and expertise? To further explore contemporary landscapes of repair, we now delve into a world of nails, screwdrivers, and multimeters in urban repair clinics like the Fixit Clinic in the California East Bay. These community-supported events were created to help average consumers fix and learn to fix their broken products, such as an iPhone with a shattered screen, a toaster without heat, or a pair of old blue jeans ripped down the backside. Like the OLPC project in Paraguay, the organizers aimed to encourage learning through electronics tinkering which, as we will see, became difficult to support in practice.

The Material Infrastructure of the Fixit Clinic

In contrast to the limited material access in Paraguay, more expertise and infrastructure were available in the repair events in the Bay Area and more repair occurred as a result. The Fixit Clinic, our primary site of investigation, is a site of facilitated repair based in Albany, California, a city just east of San Francisco. Peter, an MIT engineering graduate, founded the project in late 2009 after years of trying to coordinate a free space with the requisite technical competencies to facilitate it. He had originally tried to partner with a local electronics dealer but found that the idea of teaching repair skills to the general public threatened the store's key demographic, the trade workers whose livelihoods depended on for-profit repair services. Eventually Peter found an available community space in Albany through local contacts and recruited his first repair volunteer through his conversations with the electronics store.

Since that time, Peter and his repair volunteers, or "coaches," have hosted more than fifty events in libraries, community centers, museums and hackerspaces (community-operated workspaces, often focused on electronics tinkering) across the Bay Area and beyond, including Minnesota, Colorado, Tennessee and Massachusetts. The events operated as "pop-up" affairs, with anywhere from ten to two hundred visitors and three to thirty repair-savvy volunteers descending on donated spaces with broken items in hand. Volunteers reported enjoying showing and telling visitors how to tinker with and interrogate mass-produced items, helping them take apart electronic devices, identify broken or missing parts, and understand the mechanisms underneath.

Over the past year, Peter's Fixit Clinic has become part of a growing network of parallel sites with such names as the Fixer's Collective (New York City), the Restart Project (London), and the Repair Cafe (Netherlands). While Peter named the Fixit Clinic for its emphasis on diagnosis, he admitted that his approach was largely aspirational. "We're going to try to fix it," Peter explained, "but it's not clear we're going to be able to." As his work reveals, the viability a fix is not dependent on the product alone, but on the many factors surrounding its use and repair, including the expertise of the volunteers, the amount of leisure time available, the ease with which the issue could be diagnosed, and the parts and tools coaches and visitors had available. These events present a case of extending the use of products not necessarily designed for repair to reveal tensions within: reuse versus recycling, serendipity over planning, and the promotion of technical expertise.

Locating Expertise and Participation

What it meant to restore or maintain an item not only depended on the owner's experience with the thing but also the nature and distribution of expertise at the Clinic. As in Paraguay, it was the facilitators of repair (the coaches), and not the participating owners of the devices, that were most often observed enacting repair through tinkering and disassembly.

At one Fixit Clinic in the Richmond area of San Francisco, three sisters in their early twenties brought in a broken sewing machine they had picked up on the side of the road. Once plugged in and turned on, the machine ran at a snail's pace and eventually stopped. Guided by E., a female coach and retired teacher, the sisters spent three hours taking the machine apart, oiling its parts, and trying to adjust a dial that seemed to have broken off. When E. decided the fix was beyond her, S., a male coach with a background in engineering, suggested replacing the purportedly missing part with a short peg. He inspected the machine and found three holes on the inside of the dial. To S., the holes looked as though they had once fit small pegs that enabled the dial to turn and adjust the motor. Taking S.'s advice, the sisters found a peg-like part that matched the diameter of the existing hole, picked up a screwdriver, and proceeded to twist the screw into the hole. Forty minutes later, after several passes between sisters, the screw was ground well inside the hole.

When the sisters returned the dial to its place on the sewing machine, the result was unexpected: the machine was unable to move at all. The machine, now less functional than when it entered the Clinic, was a mystery. *What did it look like before it broke?* Out of breath and depleted of ideas, the sisters decided to return home and bring back a second broken sewing machine they had acquired, which they hoped to use as a model for how the plastic dial should look and behave.

While the sisters were away, J., a male participant with a background in engineering joined the sisters' table and began inspecting the mechanism for turning the dial. He took apart the machine from the opposite end, unscrewed the compartment on the underside, and ultimately discovered a bobbin (a small spool of thread) rolling around in the bottom of the machine. With the bobbin removed, the machine suddenly began running smoothly.

This successful fix is worth considering for the kinds of expertise it brings to light. Despite their notable investments, neither the sisters nor the coaches were responsible for fixing the machine. The eventual fix was far simpler than anyone

had suspected: removing a loose bobbin. Many fixes were like this, accomplished without owners' involvement or without their understanding of how or why a particular part failed. Disassembling and reassembling a device, and perhaps using an air spray to clear the inside of dust in between, would lead to mysterious functionality or new problems, some of which remained impossible to diagnose. Messing with a machine and exploring its possibilities for disassembly was the primary mode of repair, highlighting the value of tinkering and improvisation in the repair process.

Beyond the serendipitous character of the fix, the distribution of expertise that led to it was highly gendered. In the above vignette, it was the two male participants with engineering backgrounds, not the sisters or female coach, who decided the machine's fate, even when some of their suggestions were ultimately less critical to the fix. The fact that E. left the scene after designating her level of technical skill insufficient – though she could have discovered the bobbin herself if she had disassembled the machine, as J. had done – was representative of the majority of female participants observed passing work onto male volunteers or waiting for assistance before diving into disassembly, ultimately underestimating their mechanical competencies. Among the male participants, J. eventually fixed the machine, but S. provided advice that led to hours of trying to find and install a set of replacement pegs that never existed. The multiple interceptions of repair work by men at the Clinic were examples of broader patterns of gendered expertise and technical confidence in which some work is seen to appeal to, and align with, male over female volunteers and attendees. Peter noted,

If two or three women come to each Fixit Clinic – you know, women, because that's what they are [laughs] – and they repair fabric things there, and broken sewing machines come in, they take the lead in trying to repair those. And if not we know the other Fixit coaches will just come in.

In practice, the care of fabric, clothing, and jewelry fell to women, while male volunteers and attendees tended to take on electronics repair, reflecting the work of the tech-savvy international volunteer from OLPC and female students' relative disinterest in repair. Though organizers' aims were progressive, they still distinguished craftwork from mechanical repair and fell back on gendered divisions of labor.

Narratives of Empowerment & Sustainability

One key objective of the Fixit Clinic and other repair events was to enable learning through restoration: returning new screens to damaged iPhones, restoring heat to broken toasters, and patching a pair of tattered pants all while instilling an interest in technology development and innovation. At the Fixit Clinic, as for OLPC, repair work was seen to enable technological learning through tinkering with electronics. This motivation expanded to include ideas of technical empowerment – knowing more about technology and making more informed choices around technology as a result – and sustainability – advancing reuse over recycling and disposal.

In the case of empowerment, broken items became byproducts of diagnosis as well as materials to work with and absorb, offering new opportunities for reinvention. Peter explained:

Ultimately my surreptitious goal, which I conveyed to you the very first day, is that we're ultimately trying to get people to a place were they can help to make better policy choices. That we're demystifying technology so that when technology comes up as a societal issue people can participate in that dialogue more coherently than they're able to now.

The notion that repair work, and facilitated repair in particular, has the power to educate and transform how people see and understand technology was a common theme among coaches and organizers of the events, and was sometimes taken up by participants as well. At a Fixit Clinic in Minneapolis, a visitor brought broken antique radio that he and his girlfriend found at a thrift store. When they saw the radio, they immediately plugged it in and turned it on and the first sound they heard was an Otis Redding song that they both loved. After buying the radio and bringing it home, his girlfriend dropped it, rendering it dysfunctional. Bringing the radio to the Fixit Clinic, the visitor explained that his girlfriend's birthday was two weeks away and he wanted to repair it for her. "When he told that story," Peter later explained, "every coach was like: I want to work on that!" There were as many as five coaches vying to fix the broken radio, while Peter stood at the other side of the room already plotting to take a modern radio and somehow transplant it into the antique case as a last resort to get the radio functioning. After considerable tinkering, the Fixit Clinic coaches got the radio to play again. Several days after the Clinic, the visitor later emailed Peter to explain that before he gave the radio to his girlfriend he had checked it, and the radio was no longer working. The man opened up the radio, found that a speaker wire had gotten loose, and proceeded to fix the wire on his own. "So he was able to get it working without having to bring it to another Fixit Clinic," Peter exclaimed. According to Peter, attending the Clinic had given the man the confidence to take on his own repair. Yet, as in Paraguay, such independent repair work was uncommon (only three independent repair experiences were observed during nine months of fieldwork).

At repair events, rather than telling 'war stories' (such as the trials and tribulations that Orr's [28] copy machine repair technicians shared over lunch), coaches instead retold uplifting stories such as the radio gift as a way of rehearsing and reinforcing a desired narrative of *empowerment*. When the narrative did not match up, the story was not retold. One story rarely mentioned, for example, was of the many participants who came to fixing events for the free repair services rather than for the chance to learn about repair. For example, at a Repair Cafe in Palo Alto, an elderly man and his wife had brought in a slow-to-heat toaster he was given by his ex-wife. In use for over fifty years, the toaster was on its last legs; its mechanism for lowering the toast had weakened. Though his current wife was eager to see it die, the toaster symbolized memories the man was not ready to give up. The repair event

was an opportunity to keep these memories alive, and all it took was waiting in line. During their time at the Cafe, the couple moved between a few sets of volunteers before someone discovered that the existing spring had loosened. The toaster's performance improved when a volunteer used the same spring at a quarter of its length, creating the necessary tension to lower and raise the toast. The couple had little to do with the fix but watched as the toaster became functional once again. As in Paraguay, empowering participants to do repairs themselves was an ideal state that rarely emerged in practice.

Linked to this idealization of repair were reflections on sustainability, consumerism, and mass manufacturing. Event attendees would comment on the environmental impact of fixing devices and organizers were eager to promote sustainable processes of repair and reuse over recycling. Before launching her events, for example, the founding organizer of the Netherlands based Repair Cafe had been a journalist focused on education and then, changing focus, environmental policy. But for her journalism was not enough:

I no longer wanted to be an outsider or just a neutral describer. But I wanted to do something myself. And I wanted to really add something. And this was what turned out to be the Repair Cafe.

The organizer described feeling a "sense of urgency" as she learned of the dangers of consumerism and energy use to environmental sustainability. This kind of urgency could be felt at multiple levels and in many capacities, as it related to local events and traumatic changes. The founder of the New York Fixer's Collective explained:

We wanted to take care of ourselves and not rely on experts for our needs. And when something big happens, like 9/11, people tend to want to come together. And just human contact is important. And, you know, you can't get that by Googling your answers online.

Even as devices were removed from participants' hands, the act of tinkering with technology and taking pleasure in its deconstruction was seen by the volunteers and event organizers to change how people approached not only their devices but also technology design more broadly. Repair work incited forms of innovation that were practical and collaborative – such as the three people helping to fix the Sunbeam toaster or the six people diagnosing the sewing machine. Despite this appearance of cooperative repair and reinvention, during observations, fixes were often born out of individual tinkering: one coach reusing a wobbly spring, or one volunteer discovering a loose bobbin. This tension between collaboration and individual work, as we have seen in the OLPC program, reveals how repair becomes a privileged act, supported by technical expertise, and, in doing so, becomes political, aimed at shifting how people learn and care for their environment. In this regard, repair work and its ideological aims become embedded in networks of practice that are local and specific.

DISCUSSION

Through stories of broken devices and tricky fixes – repairing things not meant to be repaired or not being able to repair things that were – our fieldwork has highlighted some of the complicated, contingent aspects of technology care and repair. We have seen that on the one hand, communities lacking repair infrastructure – even when they do have expertise – may be stymied by a device designed (or at least intended) to be repairable; while on the other hand, communities with access to a high degree of expertise and repair infrastructure can at times overcome even planned obsolescence.

In Paraguay, the material realities of the machine and the environment, perceptions of the usability and usefulness of the XO laptops, limited access to repair parts, and socioeconomic and gendered factors all shaped the laptops' repairability. Who required, paid for, and conducted repairs were all fraught categories, revealing persistent underlying inequalities and challenging the individualist narrative of the empowered child tinkerers able to repair their own laptops. While OLPC did attempt to specifically design to enable repair, the issues that still came up suggest that designing for repair is more complicated than it may initially appear.

In public repair events, by contrast, tinkering and customization could at times recover items that may have been designed to be discarded, not replaced. Though the work to achieve a fix was often far simpler than participants or coaches expected, it was still treated as privileged expertise, accomplished by the coaches rather than the participants. Despite this division of labor, the process of learning to fix consumer electronics was cast as political action, aiming to improve environmental awareness, inform policy-making at local and global scales, and ultimately promote greater empowerment of consumers and more environmentally responsible futures.

While there are differences between our two cases, there are also a number of material, social, and ideological parallels that help us understand repair in practice. In particular, both cases illustrate aspects of what we term *negotiated endurance*. By this we mean the ways that maintenance, care, and repair are negotiated – often collaboratively – in use and the meaning-making associated with use, rather than the meanings prespecified by designers. In both case studies, we saw that the process of breakdown and repair was not something that device designers or event planners could effectively script ahead of time. Based on these observations, we argue that designers' intentions to plan or divert such outcomes can often be rendered ineffective without accounting for the specific material, economic and cultural infrastructures that are at play in use.

Although these results may point to a hopelessness in designing to enable (or disable) repair-work, as material realities disrupt design intentions, we feel that there is hope, and our findings should not be taken as a reason to abandon efforts to design to enable repair. Like those involved in repair – motivated in various ways by both ideology and necessity – we see breakdown and repair as integral parts of technology use. Moreover, despite the current trajectory toward even more

disposable clothing and electronics, we believe that repair practices may well become more important as resources become more difficult to come by, as fewer can afford replacement, as landfills overflow, and as knowledge of what happens downstream when technology is abandoned becomes more widespread. While London hypothesized that planned obsolescence would drive the economy out of depression by stimulating spending, here we promote attending to repair activities as a source of new ideas and different opportunities for development in design and engineering.

As such, we turn to our case studies and the repair literature to highlight the importance of negotiated endurance. We highlight four themes that illustrate this concept as it relates to the CSCW community: the *negotiated identification of breakdown,* the *collaborative definitions of worth* in determining what to repair*,* the *fraught nature of collaborative expertise* that repair practices surfaced, and the *gendered stakes of repair* at play throughout. Each of these themes highlights material, social and ideological parallels between our case studies.

Negotiated Identification of Breakdown

One shared theme across our sites of repair is the different kinds of breakage that people not only recognized but also made use of while working with technology. For example, breakage was not viewed as a singular phenomenon; instead, definitions of breakdown lay on a continuum. Some breakage existed without rendering a device completely unusable, yet could still be significant to the user (such as the missing keys or difficult trackpad of the XO laptops, or the Sunbeam toaster that moved slowly as it retracted). Some aspects that were understood by participants as 'breakage,' indeed, had come with the device, such as the XO's small hard drive or the bonded batteries in some consumer devices. The emergence of particular ideas of breakage also may have a complicated relationship with expected lifespans of products. While the fieldwork in Paraguay was not after the XO laptops' expected five-year lifespan, the students using the laptops nonetheless did not have much hope for an upgrade after that time, meaning that these laptops will likely be asked to perform long beyond this timeframe. On the other hand, products that might still be under warrantee at the Fixit Clinic were sometimes turned away with advice to try the manufacturer first.

We also sometimes saw that breakage could be rehabilitated without repair in the conventional sense through processes of "upcycling" or reinvention, where creative reuse enabled participants to re-envision discarded things, such as the antique radio housing a modern one or one working XO laptop made from two broken ones. As a dimension of negotiated endurance, the emergence of conceptions of breakdown in practice rather than being predicted ahead of time illustrates some of the complications for repair-work in practice.

Collaborative Definitions of "Worth"

In both of our case studies, we found that what was deemed worth repairing was tied to the collective practices in which the devices were entrenched, including the repair's economic costs, socioeconomic constraints, demands on time and effort, and social rewards.

In Paraguay, many students' families' lack of disposable income made repairs unaffordable, even when repair parts were available. As a result, laptop repairs were generally less worthy than other pressing household expenses for which income was already reserved. Moreover, because most leisure activity on the laptops involved using them as a portal to music, videos, and videogames, many parents and teachers involved with the project initially saw the laptops as a "mere toy," not something worth taking care of or repairing. While it might be tempting to blame this framing on the fact that the laptops were given out to students and teachers for free, it was more the lack of initial messages of the expense of the laptop and its potential value in the classroom, combined with this collaborative sense-making, that led to this effect. Indeed, when Paraguay Educa noticed their non-use and breakage and started emphasizing their value in the classroom, opinions on the laptops' worth changed dramatically from a "mere toy" to a "learning device," even though usage patterns had not changed as much.

Participants in repair clinics had generally already decided that a device was worthy of repair – or at least investigation – by just showing up with it, though at times their presence was more due to curiosity than by the perceived value of what they brought. Still, stories of worth being collaboratively-defined abounded. While the antique radio provided an example of a formerly low-worth product taking on significance for a couple and then the Fixit coaches, there were also cases when coaches would advise against fixing objects, particularly when the object was cheap and the repair difficult (e.g. repairing the delicate wires of a phone charger) or if the device was expensive and "official" repair might be free (e.g. broken iPhones that could be taken to Apple's Genius Bar). In these cases, coaches steered participants toward particular conceptions of worth centered around repair. These collaborative definitions of worth arose as a second facet of negotiated endurance.

The Fraught Nature of Collaborative Expertise

In our two case studies, we found interesting negotiations around what constituted collaborative repair-work, which involved negotiating between repair ideals and practices on the ground. Overall, the notion of collaborative expertise did differ from commonly-held ideas of expertise as guarded and separated from everyday use – and, as Fixit founder Peter found, could even be threatened by it. For example, while the process of fixing a car is often considered "servicing" and the main points of collaboration are dropping off the car, agreeing to repairs, picking the car up, and paying, the Fixit coaches, as well as the one volunteer in Paraguay, wanted repair to be a deeply participatory endeavor and invited attendees to adjust and refigure electronic devices much like one might fiddle with a recipe – and work with each other to do so.

At the same time, we saw that in both case studies, those who actually diagnosed most problems and carried out most repairs were rarely the owners of the device (the students in

Paraguay or the participants in the Fixit Clinics). Though in both case studies the participants were meant to be more involved, they often gladly ceded control over the repair to the staff or coaches with the most experience. Thus, though these case studies were meant to challenge patterns of expertise and could raise interesting discussions about privileged work and paid labor as well as about the tendency to replace rather than repair, they ultimately reified notions of expertise.

Still, repair work in the Fixit Clinic and OLPC classrooms afforded opportunities for socialization and tinkering, even as they ultimately reified notions of expertise as the coaches or repair staff accomplished many of the repairs themselves (whether by proxy or directly). In this way, these forms of hands-on engagement both promoted and contested the collaborative character of expertise. The task of diagnosing and repairing was passed from coaches/staff to participants, and then back to the coaches/staff. Expertise began with an ideological stance (the importance of technological learning), but was then shaped by the social relations that emerge between device owners and the repair coaches/staff, tech-savvy individuals enabled by the material training they received. As such, repair expertise is a fraught collaborative endeavor, exposing a third dimension of negotiated endurance.

The Gendered Stakes of Repair

A final theme we observed concerned the broader sociological stakes of repair. At public sites of repair, such as the Fixit Clinic, as well as the classrooms, schoolyards, and homes of XO laptop use, we have seen how repair became a privileged practice, relying on infrastructures of diagnostic and repair parts, socioeconomic constraints in defining worth, and unevenly-available expertise, all of which may be easy to take for granted until they are absent. Repair did not always become "empowering" for users in these settings. Rather, it could become a bottleneck to a working laptop, an obstacle in the classroom, a divider between rich and poor. These sociological stakes are particularly important in projects like those described in our case studies, where one of the goals was to democratize technology use and repair. The complications that arose despite these best intentions highlight how complicated and stubborn these inequalities can be.

In particular, we want to take this opportunity to critically examine some of the gendered implications of repair work in our two case studies. Despite their progressive aims for inclusivity, both the Fixit Clinic and the non-governmental organization Paraguay Educa inadvertently prompted participants to enact traditional gender roles by selectively taking up and rejecting the work of repair in gendered ways, and not challenging the assumptions that participants brought to the table as well. In the Fixit Clinics, female coaches may be seen – and to see themselves – as lacking the competencies of their male counterparts and move toward "low-tech" processes of sewing and mending, which can often be seen as less skilled and less important [8]. In classrooms with OLPC laptops, female students were more careful with their laptops and shied away from repairs performed by the all-male repair staff and even female trainers (and the author). This reticence, and the fact that it was rarely challenged, reflected established Paraguayan gender dynamics that – much like gender norms in the United States – gave boys permission to perform both rambunctiousness (leading to breakage) and technical expertise (in repair).

At both sites, by articulating differences between material practices of craft and technology tinkering, participants distinguished male and female competencies and reaffirmed divisions between gendered metaphors for technology design, e.g., low-tech and high-tech, soft and hard, gentle and rough, shy and fearless, and so on. This echoes similar findings of other researchers regarding the gendered nature of tinkering, craft-work, and repair (e.g. [8,12]) and beyond (e.g. [25]), as well as gendered patterns of expertise in computing and engineering cultures more generally (e.g. [21,24,29,45]). Our account corroborates this literature and extends it to two new sites of repair-work that highlight the stubborn nature of these inequalities, particularly the ways that gender norms are collaboratively reinforced in practice.

CONCLUSION

Building on a lively tradition of infrastructure studies, this paper has presented a picture of repair that highlights its political stakes and social contexts. Our two cases have exposed instances of design for repair in and through practice, from programs aimed at increasing technological access and expertise overseas to local sites of technological learning concerned with enhancing public awareness of environmental impacts and technological possibility.

Our discussion describes four themes that emerged from both case studies: the cultural emergence of breakdown, collaborative definitions of worth, the fraught nature of collaborative expertise, and the gendered stakes of repair. All of these are part of what we call *negotiated endurance*, in which the lifecycles of the devices were not determined ahead of time but negotiated during use around these four themes. On the material level, manufacturing limitations, access to repair parts and infrastructure, warrantee status, and even the composition of roads factored into the maintenance and repair process, whether enabling or stymieing repair. On the social level, what was first considered "broken" and then determined to be "worth" repairing was something that depended on context, including access to disposable income, perceived value of the object, and perceived ease of repairs. Moreover, those who actually diagnosed most problems and carried out most repairs were the repair staff or volunteers rather than the owners of the device (the students in Paraguay or the participants in the Fixit Clinics). This last point also relates to ideological parallels between the cases: both OLPC and the Fixit Clinic hoped that participants would repair their own devices, finding empowerment along the way, and both 'designed' with this in mind (OLPC a laptop, Fixit Clinic an environment or experience). However, on-the-ground negotiations complicated these ideologies and brought out hidden constraints and biases that could thwart them, such as the gendered nature of repair in practice.

All together, these parallels undergird negotiated endurance, the work by which different actors – including consumers, community organizers, and others – drive the ongoing use, maintenance, and repair of a given technology around the different sociocultural and socioeconomic forces at play.

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