Unmaking Electronic Waste

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The proliferation of new technologies has led to a proliferation of unwanted electronic devices. E-waste is the largest-growing consumer waste-stream worldwide, but also an issue often ignored. In fact, HCI primarily focuses on designing and understanding device interactions during one segment of their lifecycles—while users use them. Researchers overlook a significant space—when devices are no longer "useful" to the user, such as after breakdown or obsolescence. We argue that HCI can learn from experts who upcycle e-waste and give it second lives in electronics projects, art projects, educational workshops, and more. To acquire and translate this knowledge to HCI, we interviewed experts who unmake e-waste. We explore their practices through the lens of unmaking both when devices are physically unmade and when the perception of e-waste is unmade once *waste* becomes, once again, *useful*. Last, we synthesize findings into takeaways for how HCI can engage with the issue of e-waste.

CCS Concepts: • **Human-centered computing**; • **Human computer interaction (HCI)**; • **HCI theory, concepts and models**;

Additional Key Words and Phrases: Electronic waste, unmaking, reuse, upcycling, hardware

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1 Introduction

While much of our society has been structured around keeping the problem of waste out of sight and out of mind, it is increasingly difficult and irresponsible to ignore **electronic waste (e-waste)**. E-waste is the fastest-growing waste stream in the world, with reports of 53.6 metric tons of waste having accumulated worldwide in 2019 (with projections of 74 metric tons by 2030) [20]. This sheer size of the e-waste issue is a testament to needing better approaches to manage devices that break down or become obsolete, both common reasons for devices to be wasted. But, solutions need to go beyond just paving the way for more e-waste recycling. The complexity of electronic devices (e.g., being made from many materials, such as plastics and metals, and packed/soldered densely) makes them extremely toxic and challenging to recycle, often producing harmful downstream effects in polluting people's communities and the environment [4, 33]. In fact, e-waste recycling inevitably also produces waste from processing these wasted devices. Frankly, e-waste recycling simply cannot keep up to the rapid consumption and obsolescence of modern technologies. Recycling does not target the source of the issue, only attempting to remediate its symptoms. Instead, we must explore how and why electronic waste *becomes* waste and seek out methods of reducing our generation of e-waste.

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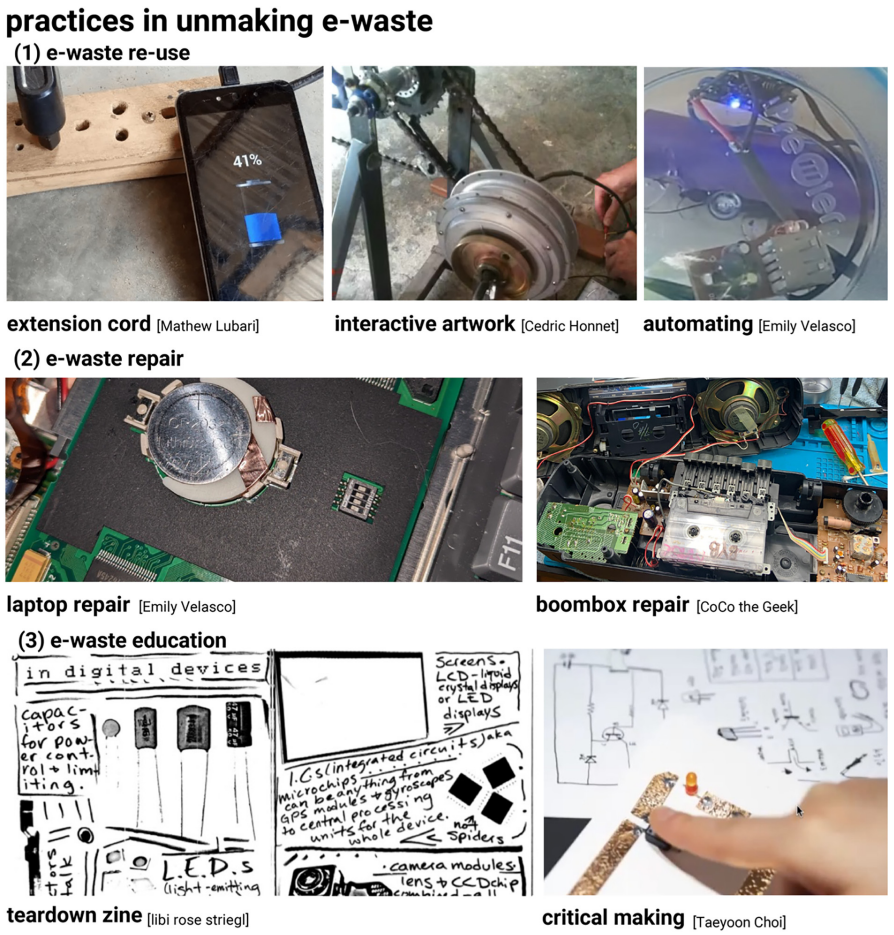

Fig. 1. An overview of various practices in unmaking e-waste. In e-waste reuse from left to right, a power extension cord, an interactive artwork using a DC motor from a washing machine, and an automatic watering system's control device made from a car charger and battery from an electric scooter. In e-waste repair from left to right, a laptop repair hack and a boombox torn down. In e-waste education from left to right, an excerpt from a Take-it-a-Part(y) zine and a close-up of a paper circuit.

Increasingly, our **human–computer interaction (HCI)** community has been challenged to adopt more just and responsible computing research practices, particularly in reflecting on how our technological infrastructures and rapid growth propel us towards the impending climate crisis. We argue that supporting methods of engaging with electronic waste and the worlds it creates are highly relevant to our community's research agendas. While electronic waste generation and flows are a product of a complex ecosystem of geopolitics, government policies on waste management, and the electronics consumer market, we argue that, simultaneously, HCI is *uniquely positioned* to explore this issue; however, to do this, we must expand from *interaction during device use*, and also account for *interaction beyond device use*, to encapsulate interactions like repairing, reusing, and recycling (such as those in Figure 1) that are not typically accounted for in user experiences.

As new consumer technologies come out every year, often making previous versions of similar devices obsolete, there are real material consequences with this pace of technology development

and rapid obsolescence. This is most clearly seen in the mobile phone consumer market, where it is estimated that there are 16 billion phones owned worldwide, and over 5 billion are expected to become e-waste by the end of 2022 [65]. Meanwhile, the rare minerals and metals to support this rapid consumption are being rapidly depleted [2, 13]. The limits of our current infrastructures were shown very clearly with the COVID-19 pandemic which induced chip shortages and stalled manufacturers' production [23]. Various engineers from industry to hobbyist started to scavenge electronic waste for parts as a means of coping with the scarcity. These interactions with electronic waste (in the discarding of or reuse of) should be part of our vocabulary in HCI as research to support sustainable practices in engaging with electronic waste is clearly needed.

In this article, we explore these interactions *beyond device use* and take the approach of exploring how various practitioners disrupt the e-waste pipeline by reusing, repairing, or recontextualizing typical electronic waste. We interviewed seven practitioners who transform e-waste as hobbyists, researchers, artists, repairers, and engineers. By diving into both their motivations for working with e-waste (Figure 1) as well as the challenges and opportunities they've found in their process, we contribute perspectives on unmaking both in the act of literally taking apart discarded electronic products and also in unmaking conceptions of electronic waste as waste to instead explore e-waste as productive material. In doing so, we build off prior definitions of unmaking as both a technical practice and theoretical approach, as well as expand unmaking to the realm of e-waste. Last, we use these frameworks to develop a series of takeaways for how the HCI community can contribute to unmaking e-waste across sociotechnical systems, calling on our community to consider their proximity and power to influence the futures of e-waste.

2 Background and Related Work

Our work draws from other works in tracing the effects of e-waste and responses to it in terms of reuse, repair, and so on. We present an overview of the scholarly work that has informed our understanding of electronic waste. First, we look to work on mapping out the issue of e-waste, primarily by geographers and anthropologists. Then, we provide an overview of ongoing work in the spaces of reuse, repair, and recycling of e-waste, noting related movements, communities, and industries. Next, we refer to HCI's previous work and its orientation toward the challenges of unmaking e-waste. Finally, we call attention to unmaking as a framework for our discussions of unmaking e-waste.

2.1 Mapping Out the Issue of E-waste

E-waste is used to describe discarded or unwanted devices. However, more precisely, defining e-waste has caused extensive legal and political debate. In some cases, devices that enter the waste stream mean they have become e-waste, but for others, it depends on the original user's discretion/situation (consider electronics collecting dust in closets). This becomes even more complicated with e-waste resellers, who can profit off selling useful parts found in discarded devices. In fact, perceiving e-waste as "waste" is itself highly contextual. Recent work from London mapped out the repairability and reusability of devices in e-waste bins and found that 36% of items could immediately be reused as is (no repairs were needed) [61]. Moreover, e-waste management approaches are significantly different across countries, further complicated by the exporting of e-waste that has often shouldered the burden of dealing with generated e-waste onto less wealthy countries. As such, precisely characterizing the extent of e-waste and its impact in a global sense is an extremely troublesome, contentious process. In *Reassembling Rubbish*: *Worlding Electronic Waste,* Lepawsky argues how distinctions in what constitutes e-waste versus non-waste have significantly impacted how we understand and measure e-waste, subsequently affecting what we believe the "right" thing to do with e-waste is and often, obscuring the complexities of industries involving

repair and reuse of e-waste [38]. One dimension of this is how scholars have argued that much of problematizing e-waste is dominated by voices from Western perspectives and dismisses the perspectives from communities most impacted by e-waste and the people doing repair and reuse work [41]. We highlight two scholars' work on e-waste: Ntapanta's work on elucidating connections between consumer electronics markets with local economies and networks of repairing, reusing, and repurposing electronic waste in Tanzania [47], and Akese's work on how problematizing Agbogbloshie as a "the world's largest e-waste dumping site" by environmentalists and activists actually led to e-waste workers being dispossessed [1]. Informed by these works, it was important to us to be critical of overly simplistic narratives of e-waste and emphasize its highly situated nature.

Notably, while better e-waste recycling and processing has been a popular call [39, 67], scholars in e-waste studies have emphasized how alternative approaches are needed, such as supporting industries of reuse and repair, pursuing right to repair and accessible repair, and exploring degrowth in the electronics industry [38]. Whereas e-waste recycling has been known to create harmful pollutants and generate waste through its complex processes [4, 33, 41], repair and reuse make do with existing materials and are highly local and personal engagements with our devices compared to the scales of e-waste recycling. Our work is similarly interested in translating the value of these reuse and repair approaches through our interviews with experts and orienting learnings towards the HCI community.

Last, while we focus on the e-waste generated by consumers, it is worth noting the abundant research that demonstrates how consumer e-waste is not the majority of e-waste. Instead, various studies have shown how a large share of generated e-waste occurs before devices even end up in a consumer's hands [10, 38, 41, 50]. Clearly, the issue of e-waste is not solely the responsibility of the consumer and their methods of disposal. However, we believe consumer e-waste offers a powerful starting point for unmaking electronic waste and all its relations. It is likely that the majority of people on earth have had personal experiences with e-waste, and to go even further, have likely struggled with how to properly dispose of e-waste. Thus, we present our work not as an argument that the solution to the e-waste issue is to have all consumers repair and reuse, but that elevating these types of interactions beyond use can encourage a less abstract engagement with the challenges of e-waste.

2.2 Practices in Reuse, Repair, and Upcycling of E-waste

Various communities actively reuse, repair, and upcycle electronic waste, and these extend across hobbyists, engineers, artists, repair technicians, and activists. For some, this work is born out of constraints where materials from scavenged sources are more cheaply accessible than new parts or because upcycling and repair work provides income. Previous ethnographic work has explored this with repair communities in Namibia [32], Bangladesh [29, 55], and Uganda [26]. More recently, due to the COVID-19 pandemic, this has appeared more widely in hobbyists and companies who were dumpster-diving for electronic parts due to issues with electronics supply chains and long lead times [5, 68].

For others, this work is born out of creativity and curiosity or a desire to preserve old technologies. Vintage computing enthusiasts preserve technologies that have long been made obsolete by mainstream electronics markets [66, 69]. Communities like *Hackaday* [12], *Make Magazine* [70] or *Instructables* [17] often feature creative projects repurposing devices. Similarly, artist have commonly used electronic waste materials in their work [31]. Hobbyists have also made teardown and reverse engineering videos to unpack how devices are designed [37, 49, 71, 72].

And last, in some cases, this work is political, arguing for the right to repair or more environmentally conscious relationships with technology. Right to repair is organized around the idea that

consumers should have the ability to repair devices themselves rather than allow companies to force consumers to only use their repair services. Key advocates in the movement for the right to repair include the *Restart Project* [73] and *iFixit* [74], producing programming around learning skills of repair and detailed repair guides. Self-organized repair cafes are similarly organized around sharing skills and knowledge to empower consumers to perform repairs themselves [26]. Across these efforts is the idea that repair skills and the technological information required for repair should be open and accessible to broader communities, not just the corporations that designed the devices.

2.3 Interaction Paradigms of E-waste and Sustainable HCI

Since Blevis outlined a vision for *Sustainable Interaction Design* [8], researchers have explored how HCI can facilitate more sustainable engagements with computing. A key theme has been the obsolescence of technology, particularly in contrast to visions of ubiquitous and smart technologies [53, 54]. This includes the planned obsolescence implemented by companies to foster continuous product consumption but also obsolescence driven by market trends with the rise of new, innovative technologies that replace existing ones [36, 51, 59, 63]. When much of our technology is expected to become obsolete, HCI researchers engaged with how to design within and against this paradigm of electronic waste.

Naturally, repair, maintenance, and reuse of e-waste have also been a focus in the HCI community. Several researchers have used existing practices to inform the development of HCI theory and design. Huh et al. explored why and how outdated PDA devices were bought and reused [27]. Kim and Paulos investigated how creative reuse of e-waste was enacted by mapping out common approaches across e-waste reuse projects [35]. Jackson and Kang looked at how artwork built from discarded technologies could engage new thinking about creativity by interviewing artist working with found materials [31]. Houston et al. highlight the derived value of repair activities across repair cafes in the United States as well as repair communities in Uganda and Bangladesh [26]. Other work has also discussed how reuse & repair approaches can inform designing for attachment, heirloom status, or longevity [9, 18, 28, 43, 48]. Last, work has begun to explore how such practices can be better supported in the design of new artifacts [15, 24, 34, 42, 44, 62]. We build on these works in looking at practices in reuse and repair to similarly explore interaction possibilities beyond original intended use of devices and how these engagements inspire new value in what was previously considered waste.

Our work is also informed by HCI scholars who call for new orientations when interacting with technologies out of concern for sustainability and as alternatives to the capitalistic-oriented values in technological "progress" [3, 7, 14, 16, 25, 28, 52, 60]. In highlighting practices in unmaking e-waste, we draw attention to how these practices resist and subvert "progress" by expanding the possibilities of devices beyond their intended purpose and even after being deemed waste.

2.4 Unmaking Frameworks

Unmaking has recently emerged within HCI as a way of thinking about technological artifacts and systems as they are "made" but also as they are "unmade," such as by breakdown, obsolescence, and decay. As such, unmaking encompasses practices that counter standard "making" practices. For Song & Paulos, "unmaking" was explored as an engineering approach of incorporating processes of destruction & decay as part of the making process [58]. In work by Sabie et al., *critical unmaking* was articulated as a participatory design approach to incorporate undoing and refusal alongside making & production [56]. In *un-crafting*, Murer et al. discuss the design value in taking things apart and crafting with those materials [45, 46]. Unmaking has also been written about across other disciplines including in discussion of degrowth [19] and design philosophy [21].

Our application of the concept of unmaking to the realms of e-waste intentionally aligns with both its definition as physically tearing an object apart as well as destabilizing the finality of a device. More specifically, unmaking e-waste involves the dismantling work inherent to reuse & repair practices, but it also involves the ways unmaking e-waste can make weird why electronic waste becomes waste when its materials can be transformed into something useful again. Drawing from the concretized list of unmaking approaches developed by the *Unmaking at CHI Workshop* [57], we see our work in unmaking e-waste as drawing from the categories of unmaking as inevitable occurrence, unmaking as sustainment agent, unmaking as resistance, and unmaking as material innovation.

3 Study: Understanding Processes in Unmaking E-waste

Objective. To understand processes leveraged during unmaking e-waste, we conducted an interview study across various experts. We define experts broadly to encapsulate the wide breadth of unmaking electronic waste that exists, and that is not well-characterized by institutions or formal education. Additionally, we use unmaking as it can encapsulate various activities relevant to e-waste, namely tearing down, repairing, recycling, reusing, and recontextualizing. Across all these activities, we see a common thread of unmaking e-waste as waste and considering it as productive material to engage with whether in a technical, hands-on way or in thinking through issues of electronics manufacturing and consumer electronics more broadly. By looking at a diverse set of experts and their practices collectively, we were interested in several research questions:

(1) What pathways led into unmaking e-waste?
(2) What are the processes involved in unmaking e-waste?
(3) What challenges experts face in unmaking e-waste?
(4) What motivates experts to unmake e-waste?
(5) What cultures of unmaking e-waste exist?

3.1 Procedure and Analysis

Participant Recruitment. Seven participants were directly recruited or snowball-recruited for their experience in reusing, repairing, or recycling electronic waste. We compensated each expert with $50 per hour of their interview time. We aimed to recruit a variety of participants from different backgrounds and geographic contexts. Our criteria for expertise was that they had prior experience in taking apart e-waste and reconstituting it in new device forms, in repairs, or for new purposes (e.g., education or artwork). The contexts in which they did so ranged for their business/organizations, personal interest, or hobbyist projects. While we aimed to recruit experts from a wide variety of domains, we do not aim to portray them as representative of whole industries or communities involved in recycling e-waste. Instead, we believe their diverse backgrounds and relations to e-waste all provide unique insights for thinking about and enacting transformations of e-waste.

Data collection and analysis. We conducted semi-structured interviews with participants about their experiences with electronic waste. Interviews took ~60–95 minutes and were conducted over videoconferencing software. These were transcribed through transcription software and manually corrected by the first author. These interviews were conducted between August 2021 and May 2023. We employed reflexive thematic analysis as our method of data analysis, combining both inductive and experiential approaches [11]. Importantly we chose this approach to note our positions and identities as researchers and do not aim to present our findings as reflective of e-waste perspectives as a whole but rather as unique and situated experiences that can offer insights. Our personal experiences with e-waste, engineering, and HCI research practices have shaped both our conversations and data interpretation. To familiarize ourselves with the data, the authors met

regularly to reflect after interviews and the first author transcribed and reviewed transcripts of the interviews. Next, the first author applied an open coding approach to analyze the interview data and constructed themes while consulting the second author. We then organized our themes, further refining them according to research question and discussing their appropriateness based on interview data.

Positionality stance and reflexivity. To frame our findings, we reflect on how our personal motivations and positioning influence our data analysis. During an earlier project on designing tools to support reusing electronic waste [42], we became interested in practices of scavenging from electronic waste and reusing it in new projects.

Both authors have experience in e-waste reuse and scavenging for components among discarded electronic devices. Additionally, both authors believe that electronic waste reuse is an often difficult process that could be better supplemented with tools and resources. Initially, we approached this project hoping to learn technical insights into processes of reuse and repair. In the process of this research, however, we recognized how issues in unmaking e-waste extend beyond the technical and are deeply intertwined with how people perceive waste and broader sociotechnical systems. Our recruitment of participants solicited those experienced in reuse specifically, but our conversations often involved other dimensions and practices within unmaking e-waste. With this in mind, we attempted to illustrate a more holistic picture of unmaking e-waste through our analysis rather than limiting to reuse or repair processes.

Both authors also support relevant movements like *Right to Repair* and environmental justice, and this may have influenced the type of "experts" we were interested in interviewing (though we believe the overlap in those that unmake e-waste and supporters of these movements is large to begin with). As researchers from a Western academic institution, we also acknowledge that we are influenced by local governance over e-waste, which may have subsequently influenced how inclusive we were and understanding of other relations to e-waste. Finally, the first author identified as Chinese-American and conducted all interviews. On reflection, this may have influenced how often Chinese markets became a focus of the conversation around e-waste reuse and recycling, though it is likely also due to China being a significant center in e-waste networks [38, 41].

3.2 Participant Bios

Emily Velasco is a science writer in Pasadena, California. She has garnered a following online through Twitter and YouTube, showing off artistic and functional projects made from e-waste she finds from a variety of sources, including thrift stores, "for free" sections on Craigslist, and on neighborhood sidewalks for trash days. Some e-waste projects of hers include a solar-powered rooftop watering system, a refurbished bike night light, and CRT TV art. She has also partnered with friends in hosting teardown sessions in community makerspaces.

libi rose striegl is a managing director at the Media Archaeology Lab in Boulder, USA. They have a history of recycling and repair originating from experiences with repairing film cameras and via a bike co-op, repairing and making new bikes. In the Media Archaeology Lab, they manage the lab's work in repairing and restoring vintage equipment (including old Macintosh desktops, Atari gaming systems, and so on). They have also organized Take-it-a-part(y)s which are workshops that give people a safe space to take e-waste apart and learn from their insides. These workshops are also featured in her dissertation titled "voluntary de-convenience" [40]. In their free time, she also creates art from e-waste, often using aesthetic parts from old devices.

CoCo Hankerson is the CEO of CoCo the Geek, a company for e-waste recycling of broken and unwanted audio equipment in Atlanta, USA. She is self-trained and learning to do things via YouTube and online repair communities. She started her business going door to door collecting

various types of e-waste before specializing in audio and music equipment recycling. In her business, she processes e-waste in a variety of ways, including tearing down devices for parts, reselling valuable boards, repairing broken equipment, and flipping/reselling equipment. She is motivated to reduce the number of devices that go into the landfill after learning how most things are not actually recycled.

Cedric Honnet is an HCI researcher and electronics engineer based in Cambridge, USA. He collects and reuses parts from e-waste personally, professionally, and in collaboration via artist residencies and hackerspaces. His experiences scavenging and reusing e-waste started from when he was a kid, identifying the usefulness of devices often found in the trash. He has since facilitated reuse, repairs, and hardware hacks in hackerspaces he started, where they build devices for people who cannot afford new ones (i.e., fixing laptops for a person who is homeless). While he is a student in the United States and is from France, he has experience in doing projects with e-waste reuse in various countries like Colombia and Indonesia and frequently makes trips to explore the Chinese electronics industry.

Taeyoon Choi is an artist and lecturer in Seoul, South Korea, and lived previously in New York as a cofounder of the *School for Poetic Computation*. He has recently started organizing a series of e-waste workshops and is conducting research about electronic waste geographies with a decolonial and anti-capitalist lens. His first workshop (in Seoul) combined a discussion of the e-waste problem with hands-on critical-making activities where participants learned the basics of constructing circuits (soldering, using a multimeter, and understanding how switches/LEDs/transistors work). He believes in giving people the tools to understand why devices break and believes a drastic change in the user relationship to devices is needed to reduce consumption and production of e-waste. He also has prior experience in reusing e-waste for art projects and in managing the generation of e-waste through new media art practices.

Honghong Lu is electronics engineer currently based in Amsterdam, Netherlands, with experience in large-scale electronics manufacturing in China. She has various projects where she either upcycle e-waste for personal projects or uses e-waste to inspire client projects for *Blinkinlabs*. Her process often involves prototyping with devices that are commonly available and using their designs to inform how she approaches her own projects. Additionally, she has seen how practices in managing e-waste have changed in China, including from perspectives within manufacturing factories, the e-waste reseller markets, and community management of generated e-waste. Last, she regularly frequents online Chinese e-waste resellers that can be rich sources of information on reuse and reverse engineering.

Mathew Lubari is a self-taught repairer and activist in the *Rhino Camp Refugee* settlement in Uganda and the cofounder of *Community Creativity for Development*. He is a refugee from South Sudan and now provides repair services and training on e-waste management for the refugee settlement. Through his work, he's an advocate of ethical repair, reuse, and recycling of electronics and raises awareness about e-waste. He advocates learning skills for repair as a form of empowerment, especially in his local community with various constraints of resources, travel, and tools. He actively runs repair cafes and digital training workshops and has done projects repurposing components from e-waste, such as building a solar charger, power extension cable, LED flashlight, and automatic hand-washing soap dispenser. Currently, he plans to build out a makerspace to better support repair activities and sharing repair knowledge to his community.

4 Findings

In this section, we present the result of our reflexive thematic analysis. In our presentation, we identified which of our participants expressed what by their name rather than using identifiers, as

Table 1. An Overview of Constructed Themes Organized Around Each Research Questions

Research Question	Constructed theme	
Pathways	Developing expertise through projects Unmaking out of curiosity Frustrations with repair/recycling services	
Processes	*Technical processes*: Engineering within constraints Looking inside: making use of common components Embracing market influences	*Pedagogical processes*: Providing a safe space for exploration Connecting to personal experiences
Challenges	Getting into more than you anticipated Lacking access to resources Being subject to manufacturer policies Consumer electronic trends	
Motivations	Unmaking as an alternative path of learning Unmaking as a form of resistance Unmaking as remediation Unique materiality of e-waste	
Cultures	Mentalities of fear and lacking expertise In/Visibilities of e-waste Networks of e-waste Valuing repair and maintenance	

it felt important to acknowledge their specific contexts and experiences. We developed 20 themes and organized them according to subject matter for clarity. A summary of these themes can be found in Table 1. We organize our themes according to our main research questions: pathways, processes, challenges, motivations, and cultures in unmaking e-waste. In discussing our findings, we use the term unmaking to encapsulate the various processes of repairing, reusing, recycling, upcycling, tearing down, and reframing of electronic waste. Notably, various terminology was used by our participants to describe their practices. In reporting our findings, we use unmaking to discuss these processes more generally and use specific terms like repair or reuse when discussing findings specific to those practices.

4.1 Pathways Toward Unmaking E-waste

Our experts discussed various introductions to their practices of electronic waste. While some experts engaged with unmaking e-waste since childhood, others only recently started to integrate unmaking e-waste into their practices. We discuss their pathways to unmaking e-waste through the themes: (1) developing expertise through projects, (2) unmaking out of curiosity, and (3) frustrations with repair/recycling services.

Developing expertise through projects. Unmaking e-waste requires technical skills such as identifying and testing components, but our participants emphasized that getting started with unmaking e-waste could be done without expertise in electrical engineering or related fields. While Honnet, Lubari, and Lu all had some form of formal education related to engineering or information technology, Choi, striegl, Hankerson, and Velasco share backgrounds in art and discussed these backgrounds as contributing to their start in unmaking e-waste. Similarly, Honnet and Lubari expressed how they sought out degrees in technology with the aim of becoming better able to repair devices or understand their inner workings, but learnings from programs were a small part of their knowledge and skills in unmaking e-waste. Velasco noted how her lack of a background in "electrical engineering or writing computer code" at times has prevented her from unmaking more complex electronics. However, she start to learning about how to

reuse electronic waste was primarily through hands-on experience across various projects. This method of building skills and expertise by "doing" was also emphasized by striegl, Lubari, Honnet, and Hankerson.

Participants also often discussed how need-based projects led to their explorations in unmaking e-waste. For some, this came out of having resource constraints. For example, Honnet described how growing up, he was in a community that did not have as many resources but had a culture of tinkering, leading to projects like building a laptop from parts when he did not have the money to buy a new one. Velasco similarly discusses how parents who encouraged reusing and fixing were key, describing it as a mindset of "Why buy something when you can fix something? Why throw something away if you can find a way to use it again later?" For others, frustrating experiences with going to a technician for repair were a key factor in why they learned repair skills themselves. In Lubari's case, he wanted to develop skills for repair after a repair technician's process was kept hidden to him, and learning the method himself gave him agency to perform the fix as needed rather than rely on the technician. This prompted him to go further and seek out repair skills through self-directed learning (e.g., YouTube).

Unmaking out of curiosity. Taking things apart just to see how they work was a common start for many of our participants. Several noted disassembling things as a kid as a key part of their journey towards unmaking e-waste. For striegl, what started out as taking out electronic and mechanical parts from things purely for aesthetic purposes gradually evolved into practices of care and maintenance of devices and eventually into functional reuse of components during their MFA and after. Honnet recalls a childhood loving "opening things, destroying things" even though he "had no clue how to put things back." For Lu, this came through in two ways. First, her background in manufacturing allowed her to think about devices in terms of functionality but also in terms of the components inside them. Her experiences seeing how in toy manufacturing, toys that often looked completely different on the outside had the same or similar parts on the inside. This allowed her to use this thinking in figuring out creative solutions to prototype with existing devices rather than build from the ground up (i.e., using e-cigarette lighters to heat up and pop balloons for a display or be inspired by poultry tracking devices for a client's pigeon art show). Second, she described how she enjoys perusing Taobao e-waste resellers often out of curiosity. While sometimes this process can inspire ideas for her projects, she describes it as primarily "window shopping" to see what exists because there are a lot of interesting things that pop up.

Frustrations with repair/recycling services. Another common theme was that frustrations with existing repair services led them to think more critically about electronic waste. In Choi's case, he discussed how he attempted to repair an old laptop himself and when he failed, he found repair services did not make sense financially. This consumer experience was mirrored by his experiences teaching computer programming and electronics to artists. He explained, "*there is a bit of a responsibility that I felt in every workshop of creating these kind of DIY, crafty things, but also, that are essentially trash. So, I had to justify to myself, what is the value of this work? And what are the real kind of environmental costs that we are paying with doing this kind of work?*" The lack of "good solutions" when it comes to repairing or recycling discarded electronics was emphasized in many of our discussions. Lubari similarly discussed how in one experience, trying to repair a broken laptop during university, unethical repair practices and voided warranties from previous repair attempts made him unable to repair his laptop, and instead, he had to sell it for e-waste scraps, significantly depreciating its value. These kinds of experiences led him to make teaching "ethical repair" a priority. For him, this involves teaching others not to remove necessary parts of an item, not tamper with a client's data, how to properly resell valuable components when a repair is no longer an option, and properly compensating clients for parts.

4.2 Processes in Unmaking E-waste

To address our second question: *what processes practitioners employ when unmaking e-waste*, we organize our themes into two sub-groups: (1) technical approaches and (2) pedagogical practices in teaching skills in unmaking e-waste.

4.2.1 Technical Approaches in Unmaking E-waste. There are many technical processes to repair and reuse of electronic waste, including taking devices apart, identifying components and circuit patterns, desoldering and soldering components, and testing components. Within the context of repair and reuse, these processes become more complicated when combined with device obsolescence, broken/destroyed conditions, or lack of spare parts. Moreover, our participants described how the type of thinking required was very different when engineering with e-waste. Through our conversations with participants, we constructed four themes on their technical approaches to unmaking e-waste. These themes include (1) "engineering within constraints," (2) "looking inside: making use of common components," (3) "embracing market influences," and (4) "always have a plan B."

Engineering within constraints. A common theme was how working within the constraints of what materials were available required them to change their engineering approach. Rather than build from the ground up, buying materials as needed, participants expressed how they would allow their projects to be guided by the materials available instead. For instance, Honnet described how when he had a project idea in mind, he would seek out specific devices that he knew had the necessary parts or functionality. In cases where a certain component could not be secured, the team would transition to a different interaction mechanism. Notably, in documenting artistic projects where components were salvaged, he often uses more general descriptions for where to acquire parts such as "laser from any dead CD/DVD reader/writer" or "quadrature encoder from any mouse scroll," highlighting and encouraging a process of operating within the constraints of commonly available electronic waste.

Engineering within constraints also meant becoming comfortable with destroying prototypes throughout the process, allowing unmaking and remaking to go hand and hand. For striegl, this meant challenging the idea that the things you build must "remain static." For them: "*I've destroyed everything I make because I need to use those parts. I'm not gonna buy new parts when I already have the parts. I'm just gonna take it apart. I destroy that thing, and then remake it into something else.*"

Lu's practice often involves connecting project ideas (for the design studio and for personal use) to how the idea could be achieved with common devices. For example, for a client who wanted to create a tracking bracelet for pigeons during flight (requiring low weight and small size), she took inspiration from a company that sold chickens and guaranteed a level of food safety and quality by tracking their chickens through a small wearable and allowing consumers to track the chicken's movement over a phone app. She purchased a chicken from this company out of curiosity, and the chicken still had the wearable attached when it arrived, allowing her to see how they accomplished their design for her own project. Even in an incredibly specific project (a pigeon wearable for an art show), one can find commonalities with what already exists rather than needing to invent anew.

Looking inside: making use of common components. Like in Lu's story, leveraging how many devices have common electronic components or incorporate common design patterns was an important part of repair and reuse for our participants. Many discussed stories of creating or fixing one device by using multiple of the same device. In an era of device obsolescence, this is a popular strategy as e-waste might contain dozens of the same device. Taking components from other similar broken devices also tends to be a much easier source of spare parts than contending with supply chains. Hankerson explained: "*these parts here, they came out of machines that were destroyed and cut up [where] I'm not gonna be able to repair them. Instead of holding onto the whole machine, I pull*

out the components (...) So say we had a unit that came in and one of the potentiometers was broken and it uses this one, I can desolder this and replace it."

Common component types also allowed for creative repurposing as standard communication protocols or libraries made various sensors amenable for use in a different system. In talking about a project collaborating with an artist to make interactive exhibits from e-waste, Honnet explained:

"Sometimes we already knew what we wanted so we would go to the [e-waste disposal] place and we would look for anything that has a remote control because we knew there would be an infrared emitter and receiver. We would look for a mouse because we knew... in the mouse, the scroll sensor, we [can] use that. It's very easy to interconnect because that sensor appears as a USB device. And if you know how to receive the data in Python (...) we would just have the Arduino send like a keystroke to do image per image on a player or VLC... [For another project], we put this rotary encoder recycled from a mouse and we read it with the Arduino... I was using an encoder library, so you can count how fast you go and you can also measure in which direction you go. So you can play sounds [depending on] the variable speed in a variable direction, basically, that was inspired from scratching with vinyl. All these tools, they use the same approach, quadratic encoders. And so, these libraries are fairly accessible or even simple to implement yourself."

Last, becoming familiar with the common components *inside* devices was essential for testing and troubleshooting strategies. Our participants lamented how broken devices were often simple fixes away (which mirrors other reports on repairability of e-waste [61]). Participants consistently described practices like checking for blown capacitors, resistors, or fuses, broken traces, bad belts, and switches as some of the first activities they would do to test or troubleshoot a device because they were such common culprits. Hankerson explained: "*You can sometimes look at the capacitors and they'll be exploded or leaking, and you can know. Because I've been dealing with audio stuff for so long, (...) you get a hum noise, and you know you probably got bad caps in the powerline. Certain things you already know.*" For striegl, she characterizes herself as "*not knowing how to repair things but knowing how to take things apart and figure out how to repair things*" and explained: *"Once you get familiar with looking at the insides of electronics, they stop being an overwhelming mass of components pegged on a green board and start being like discrete things that you can identify."*

Embracing market influences. Navigating various markets around repair and reuse was also key in our participants technical approaches to unmaking e-waste. Sometimes, this took the form of accounting for the availability of spare parts or repair services but also appeared in surprising forms like using marketplaces to get strategies for reuse.

For Hankerson, running a business in recycling e-waste necessitated an understanding of the market of e-waste. First, her business model is to prioritize reselling first then donating and recycling as a last resort. After moving to focus on A/V equipment, she says "80 to 90 percent of what I get is resellable." Also, recognizing the different types of buyers affects her approach to resell. For example, vintage computing markets are often well-equipped to properly service and preserve equipment, so she feels comfortable selling broken devices to them, knowing they are unlikely to just be trashed or sent to recycling. Last, she tries to price repairs appropriately, recognizing cost as a main barrier to repair. Repair shops oftentimes overcharge for simple fixes. She explained, "*When I repaired this turntable for this guy. That part – a 14 cent part - it took me literally two minutes to solder, take the old, put it in. If you would have took it to one of these bigger repair shops, they would have charged. He actually took it to a repair shop and they said they couldn't fix it because they couldn't find the parts. What they were trying to do was replaced the boards. I don't replace boards. I replace components."*

With Lu and Honnet, they often looked to Chinese e-waste markets to pick up on information related to e-waste. These markets are the world's largest parts markets and are rich with technical information and strategies for electronic waste reuse in recovering parts, identifying parts, and

reverse engineering components. Honnet recalls electronic waste marketplaces he saw when traveling in China (2016–2018). He describes how significant reselling of harvested electronic parts already exists: "*there's actually a building just for recycled parts.*" He recalls seeing many vendors sitting on the floor and meticulously separating components from their boards: "*These people are actually serious about the way they do the recycling. They cannot test everything, but they can recycle it in a clean way. And then, they bake the part in case there's any humidity... and most of the time, they're actually fine.*"

Identifying parts is a significant challenge in the reuse of e-waste as manufacturers all have different strategies for labeling parts (sometimes intentionally obscuring what they are), making it difficult to search through databases to figure out what the part is. Honnet described often using Chinese online marketplaces (e.g., *AliExpress* or *Taobao*) instead to identify parts, often having better success searching for documentation on poorly labeled parts compared to other search engines because there are likely people already reselling it. In a similar vein, Lu identified comment sections in e-waste product postings as rich sites for finding how to reverse engineer or get components to work. Lu stated: "*The comment [section] on each item they are selling on Taobao is like a community. People will [give] feedback [on] the things. (...) People will say 'I got this e-waste (...) I thought this was the worst part, but I bought it and modified here and [now,] it works'. People put a whole dialogue onto the comments there. Sometimes they have an [illustrative] photo or image.*"

4.2.2 Pedagogical Practices in Teaching About Unmaking E-waste. Almost all our experts have experience in teaching unmaking e-waste. For striegl, Velasco, and Choi, this was in the form of workshops for tearing down devices or thinking through the issue of e-waste with hands-on circuit building activities. Honnet provided support in hackerspaces, and Lubari is as an educator in repair cafes and in his organization. Hankerson also describes seeing educating the community as part of her business and work, helping people understand processes in electronics recycling and be more thoughtful about their own e-waste. We developed three themes from our participant's discussions of crafting educational experiences around unmaking e-waste: (1) Providing a safe space for exploration, (2) do-it-together (DIT), (3) connecting to personal experiences.

Providing a safe space for exploration ("It's okay to make mistakes"). Unmaking e-waste can be intimidating, so our participants discussed how providing a safe space to explore and ask questions was essential to having people become comfortable. In describing how she supports volunteers in repairing old devices at the Media Archaeology Lab, striegl explained, "*a big part of this is just you have to give people free rein to make mistakes because it's gonna happen and it's not a big deal. It's not a big deal if somebody makes a mistake and something gets broken because it was already broken.*" This was also a fundamental part of striegl's *Take-it-a-part(y)s* [75] where she would also intentionally provide broken devices to take a part so that "there's no emotional attachment to it" and that participants know that "it was just going to be recycled anyway", allowing them to have less anxiety about it. Similarly, Velasco recalls the Teardown Academy she organized with a friend: *"We told people: 'Come! We have all these tools, bring something that you want to take apart and learn how it's put together and what's inside of it'. And we told them (...) we want you to take things apart and learn how they work so that you, one, don't have to be intimidated by taking stuff apart, and two, so you can start to see how stuff is built and how it works."* Honnet also recalled how e-waste was also a great way to practice soldering and desoldering in hackerspaces. Giving a safe space to do curiosity-driven unmaking allows people to learn skills and get through the fear barrier of unmaking, and doing so with e-waste also offers the added benefit of using materials that are already "wasted" so mistakes are less of a concern.

On the other hand, our experts were also mindful about how they themselves facilitated learning. For Choi, this meant approaching the topic of unmaking e-waste empathetically, believing it "not

best to guilt trip people about these things" as finding "correct" solutions to unmaking e-waste can be unproductive. Instead, emphasizing learning about devices to think more critically about unmaking e-waste can allow us to reflect more thoughtfully about our relationship to technology. He explained, *"when we are making these circuits, we are creating another e-waste. But I think my hope is always to change the relationship people have with electronics and computational devices, so if they understand how a switch works or how a push button works, they can also understand how when their vacuum cleaner does not work, it's actually just the switch not like the whole entire thing [is broken], so consequences of that could be positive in the end."*

Connecting to personal experiences. Last, our experts often connected their teaching of unmaking e-waste to others' personal experiences with e-waste. With technologies so ubiquitously embedded in our lives, everyone has experiences with generating e-waste and likely, being unsure how to properly dispose of it. This often served as a useful starting point to allow people to critically engage with e-waste. For example, as part of Choi's e-waste workshop, he asked participants to bring in e-waste from home and share stories about it. One of the workshops participants brought a handheld electric fan and explained they got multiple for free at events, all eventually breaking, and they were unsure what to do with them. Another participant brought the front panel of an iPhone, describing an attempted and ultimately failed repair of an old phone. While his workshop centered around more abstract discussions of industries of recycling e-waste, ethical issues in the shipment of e-waste to other countries, and thinking critically about the issue of e-waste, this portion of the workshop allowed workshop participants to connect these things to their personal lived experiences.

In discussing what he hopes participants take away from his workshops, he explained: *"I think that's actually the key. It's that unmaking and unlearning and challenging the ways we use products, the ways we produce devices. That's very different from trying to find a technological solutions to e-waste, or legal solutions to e-waste, which are both important, which need to happen, but also unmaking and critically engaging, could be a way in which that we fill the gaps where the policy and the technology does not fill, which is actually the human relationship with technology... recycling smart devices or like recycling my vacuum cleaner. does not help climate crisis or environmental change in a quantifiable way because it is so small compared to the fossil fuel industry, or the whole idea of smart cities, [or] as e-waste. But I think what it does is it changes people's relationship with consumerism, and objects, and the environment. And it changes the way that we think about larger policy changes about energy and environmental resources. My hope is that by changing our relationship with our devices, we change our relationship with the habitat at large."*

4.3 Challenges When Unmaking E-waste

Various barriers can make unmaking e-waste challenging. As a non-traditional pathway to engaging with electronics devices and often one not well supported with documentation and resources, our experts constantly must make tradeoffs. In analyzing how our participants discussed the main challenges of unmaking e-waste, we developed four themes: (1) getting into more than you anticipated, (2) lacking access to resources, (3) being subject to manufacturer policies, and (4) consumer electronic trends.

Getting into more than you anticipated. Our experts all expressed that there are many more factors to account for in unmaking e-waste. Repairing devices or reusing e-waste for new projects often entail non-linear paths, requiring extensive time, energy, space, and money. A reality is that sometimes these costs of pursuing unmaking e-waste cannot be justified. Velasco described her experience as often being "penny-wise, pound-foolish" referring to how sometimes opting for what seems like a hack by using repurposed materials often might entail multiple prototypes and failures which could have been avoided by opting for the simpler route. She says,

"I don't want to just go buy this thing that's the right thing for this project. I'm gonna try to cobble a thing together. And then by the time I've cobbled it together, not only have I wasted a lot of time, but I've gone through like six versions of it because it won't work. And then I ended up spending more money and using more resources than I would have just doing it the right way in the first place."

Another process that easily becomes a rabbit hole is reverse engineering devices and identifying components. As striegl describes, *"a big barrier is when it comes to identifying parts, and then not being comfortable testing and developing your own datasheets. Even I am not fully comfortable, especially with some of the microelectronics. I always save cameras out of stuff but am not fully sure how I can go about repurposing their chips always. If I can find the part number, then I can sort of slowly start to dig in. (...) I don't always have time to figure out how to use this thing, so I just put it aside. I think that happens a lot for people - I know what this is, but I don't know what the pin outs are. I don't know what the voltage tolerance is."* These processes of identifying parts, finding relevant datasheets, and understanding how to properly connect them in circuits can all take hours or days and often just lead to dead ends.

Hunting down required parts to service a device can also become a long, winding journey. Hankerson recalls previous experiences where purchasing a spare part for repair would cost close to the same amount of buying a completely new device. Lubari also discussed situations where specific types of parts were needed for repairs:

"We sometimes go to the nearby city or town [in Uganda]. But mostly in the nearby town, we find that in most cases, they don't have those batteries. We have to give an order, and then they order either from the main city or sometimes what they do is they have to order it from UK or from any European country and then it takes weeks to come... [Another] thing is without a technician, replacing a component is more expensive. For example, a mobile phone screen. To replace it, it's more like you're buying a new phone. So people tend to [be] like, why should I have to waste my time to replace them if when I give them the money for replacing, it's equivalent to buying?"

Lacking access to resources. Our experts often recalled moments when their unmaking projects hit a wall due to insufficient resources or missing support in key areas. All our experts unmaking practices were not supported by a big business or recycling facility, instead they were often working out of their personal workshops or in smaller community spaces. As such, many did not have the needed tools or facilities required for unmaking, limiting them in the type of unmaking processes they could employ. Lubari described how they would often find a creative solution to constraints of lack of proper tools or lack of consistent electricity by using bicycle spokes as soldering tools: "*What we used to do [was use] bicycle spokes where you heat it and put it in fire and use it for soldering. But of course, over time, when the soldering irons, when they became common, we eventually got the soldering iron, but with the bicycle spoke, you don't need electricity. You just need fire to heat. Of course, it does not do it perfectly the way a soldering iron does.*" Lubari also mentioned other tools he wishes he had like microscopes, PCB holders, hot air guns, and particle blowers—all would make the process of repair easier for his community. Lubari explained that in partnering with other repair communities (like from Germany), their repair approaches are notably different as they are often better equipped: "*we are not [as] well equipped in terms of tools and the knowledge. On the other side of the continent, they have well equipped facilities where they run those repair cafe events... we use conventional tools to make things work.*" Similarly, Velasco described that even with a well-equipped workshop, there are always other tools that she could benefit from: "*I have a little bit of stuff in my workshop, (...), but I don't have access to a machine shop. (...) And without a machine shop, I just don't have the ability.*" And last, particularly with taking apart small devices, Choi explained how doing so "required more of a facility for safety" and the average person is unlikely to have access to such facilities.

Our experts expressed a desire for more resources that more clearly and accessibly communicated relevant reuse knowledge. Using online forums was a common approach to locate and identify information for reuse & repair. As these sources were often more ad-hoc and dispersed throughout various sites, it is not usually easy to locate needed information. In imaging what kind of resources would be ideal in supporting her unmaking practice, striegl reflects:

"It would be nice to have a more centralized user generated space – like a repair and reuse wiki or something where there is a forum that you can add to, expand on, create new articles, drop in schematics that you find because a lot of it is just scraping through forums and finding [stuff] all over the place. It's so nice if we could encourage people to do some sort of centralized thing – like a go to resource. Even if it's something that does some web scraping and gathers. Like, I want to look up this particular part number, and that search leads to all of these different forum posts that have been scraped from somewhere else. That would be great because then I wouldn't have to find [information through multiple] forums, I can just find them all in one place."

Honnet also recalled how documentation is often lacking in these user-generated sources of information, as "it's usually very incomplete because it's hard." He also wishes for "good, centralized information like a Wikipedia for electronic parts." Velasco similarly recalls frustrations in watching various YouTube videos (or scouring other sites) looking for information, but code or schematics which contain the information needed are often not attached or linked.

Being subject to manufacturer policies. In unmaking e-waste, the process often entails tracing spare parts or device documentation back to the device's original manufacturer or company. Often, companies do not prioritize maintenance of previous versions of their device or refuse to provide documentation for repair. In these cases, our experts had to find alternative sources of information or spend time to generate the knowledge for themselves. Hankerson recalls a frustrating experience with a company's support services when trying to acquire a spare part for repair: *"Until the manufacturers can become responsible for the products they make, it really starts there. They have to start making products with better components, and they have to also make their stuff more serviceable... [For an audio brand] I called their part department, like a day or two ago, trying to get replacement parts, they gave no help – 'Oh, that product is discontinued. We don't have any.' They couldn't give me a part number. The thing the guy told me, 'Oh, just go on eBay or Amazon, you might be able to find it.' Well, I can't find it on there because obviously I did that before calling... But that just goes to show you: if a consumer wanted to get that fixed, they couldn't because even a manufacturer is not trying to help me fix it. I was like y'all, you didn't even take the time to see if maybe y'all use that switch in something else and maybe y'all have a spare part, so it just blew my mind."*

Our participants emphasized how much of the electronic devices made today are made with planned obsolescence. Lubari discusses how these manufacturing policies can really negatively impact repairability in secondhand electronics markets or with donated devices: "*The market is full of having a lot of not long-lasting items. You buy it, and it stays on for one month. That's terrible. Some of those ones that are not long-lasting, when you try to repair them, you cannot repair them, and you cannot get a spare part.*" Such practices can work insidiously in favor of companies who benefit from planned obsolescence as a means of encouraging buying new devices instead of regular repair and maintenance of existing devices. Honnet described how he has seen these priorities play out in how products are designed: "*because they are built to be destroyed, you know, about programmed obsolescence, these things are very well tuned. They know that after a certain amount of time, certain amount of movements, it really will break. They know it will be just after the warranty. All these things are very well tuned.*" Working with devices that are intentionally designed to resist longevity is a frustrating and sometimes, a seemingly futile experience.

Consumer electronic trends. The way popular consumer electronic devices have been built has drastically changed across the decades. Increasingly, devices are designed to be small, cheap, and

ubiquitous. While this might seem like a good thing, these trends are a significant contributor to e-waste by making repairability and reuse extremely difficult.

Hankerson and striegl both emphasized how older devices were much more robust and amenable for unmaking. In Hankerson's words: "*You got equipment that was made in the 70–90s, maybe early 2000s, and they're still going, and outlast equipment that was just made in the last couple of years.*" Meanwhile popular cheap Bluetooth speakers that are "very consumer plastic cheap" are just "not worth repairing." As striegl explained, *"The nice thing about old stuff is it's relatively simple, so it's pretty easy to find a computer from the 80s that you turn on and it's fine. [It's] comparatively less easy to find a computer from the 2000s that they turn on and it's fine. I have more trouble with newer stuff than with older stuff, but there is also a greater proliferation of newer stuff... In some cases, it's just not practically feasible at all to try and maintain stuff from the 2000s versus the stuff from the 1980s."*

This also applied to how easily parts could be scavenged from devices. With trends in making devices extremely small, the processes to use and reuse components of sub-millimeter size can only be achieved with specialized tools. Meanwhile older devices are more accessible to take from as striegl explained: *"The older it is, the bigger the shit inside of it, so the easier it is to identify stuff, so the more comparable to off the shelf parts it is, and the more likely someone else has dug into it and created a data sheet for like all of those things. Older computers, I can repair with off the shelf parts. They have big giant capacitors and big giant resistors and a lot of them were hand soldered anyway. And they have through hole components. It's not surface mount stuff, so it's a lot easier to like reclaim stuff from older devices."*

Choi connects this to broader consumption patterns in a capitalistic world, using the issue of e-waste to explore how capitalism is in conflict to producing quality devices that might last longer and, ultimately, be better for the environment: "*With smart devices, it's getting cheaper and cheaper because of competition, but it's actually costing more to produce. Possibly the more ethical way for business would be, just charge more and make a better product, but capitalism doesn't work that that in that way. Capitalism works in scale and competition, so we end up having inferior products that are slightly cheaper, more often."* Practices in unmaking e-waste do not advance a capitalistic agenda as repair and maintenance do not promote continuous consumption but rather utilizing what already exists. Similarly, the churn for new, small, cheap, and ubiquitous devices makes millions of existing devices obsolete, creating immense costs in (ideally) recycling and reclaiming these resources or in downstream environmental effects of e-waste pollution via landfill dumping. These costs are not reflected in the average monetary cost of consumer devices and are extremely hard to quantify. However, their impact to the logics of electronics economies and resulting barriers to repair, reuse, and recycling is lasting.

4.4 Motivations

Unmaking e-waste is difficult work, but our experts also expressed finding joy and purpose in this work. They were motivated to keep pursuing these projects because of unique benefits in unmaking e-waste. We frame our experts' motivations along four themes: (1) unmaking as an alternative path of learning, (2) unmaking as a form of resistance, (3) unmaking as remediation, and (4) unique materiality of e-waste.

Unmaking as an alternative learning path. As discussed previously, the technical practices of unmaking e-waste involved learnings that were often unique to repair and reuse and not usually included in formal engineering education. As such, our experts often discussed how there was special value in learning via explorations of unmaking.

Velasco explained her projects allowed her to develop a sense of what could be useful and expanded her technical abilities: *"I think the more I've learned about electronics, the more I've realized what things are useful. It used to be that maybe I would just save like pieces of wood or metal that*

I found on the street. But now I have some idea about what kind of things in electronics might be useful, what kind of mechanisms can be useful, and then ways I can repurpose them, learning more about electronics and more about writing code, and all that kind of stuff. And that cluster has, I guess, expanded my horizons in my ability." Each device can be seen as a treasure chest of new knowledge and skills to develop, allowing new learnings which each unmaking.

Unmaking devices to encourage more creative thinking with electronics was a key part of striegl's work and a focus of their dissertation. She described how unmaking enables a different engagement compared to more traditional electronics engineering education where "*people are brought into the first level, but there's no clear paths to the next. They're brought into the first level of following the steps of a kit which are following the steps that somebody else has done, but it takes more focused education to get people to consider the other possibilities of something. And that's why you see a whole bunch of physical computing art that's just variations on the blinking lights. There is no more sophistication than that, (...) it's, I think, partly an error in the way things are taught. You can also use the blinking light sketch to control a motor, they're the same thing. You can teach people that actually the output can be any number of things. (...) So I think that's where there's a big [issue]. We unintentionally narrow people's field of vision from the very start in electronics education in a way that doesn't facilitate the sort of exploratory creativity that taking something apart would be part of.*" Unmaking allows us to expand the value of components beyond their original use in a device so that more critical and creative engineering skills can be developed. Hacking, modifying, and repurposing devices empowers people to use their engineering skills in out-of-the-box ways.

Unmaking as a form of resistance. While our experts did not necessarily always discuss their unmaking work in terms of activism or resistance, the underlying motivations of pursuing their unmaking work often pushed against the norms of e-waste. This came in various forms whether that was for reducing e-waste for environmental reasons, empowering individuals in their ownership of devices, or resisting conventional interactions with electronic devices. For striegl, the political and environmental issues of e-waste are the main motivating factor for her repair work, which she explained: "*It's the reason that I repair things. It's the reason that I believe that we should have the right to repair things. It's the reason that I believe that copyright and intellectual property are immoral and have been weaponized in ways that are only beneficial to the well-being [of the companies] and are ultimately, like, creating environmental disaster.*"

Teaching skills in unmaking e-waste also served to empower individuals when their devices broke down, allowing people to resist planned obsolescence. Lubari identified this as being important to vulnerable populations who can be put in risky situations waiting for device repairs, such as the refugees he works with in the settlement. He explained:

"By and large, most of the refugees, they move a distance of about 60 kilometers in search of a place to repair their gadgets, and it's costly in terms of transport. And then also, you've reached there, and your device is not repaired at the same day, so you have to wait for longer in the city. But it's the risk moving on the roads, for women especially. There are issues along gender-based violence that are caused and create a lot of issues. This repair cafe events that we created, it acts as a tool for peacebuilding because it brings people together, who are willing to share their knowledge and skills with those who are not having that skill before."

Last, Hankerson also spoke to how the way she runs her business resists contributing to common unethical practices of recycling e-waste. She explained, "*you can preserve more because you want to... there's a difference between wanting to keep stuff out of the landfill, versus wanting to actually preserve it for another reason, because we can take stuff to a recycler and yes, it's not going to go to landfills. But what are they actually doing? Are they selling this stuff to a third world country? Because that's another thing, (...) I don't want to contribute to that, so I want to only deal with products that I know that I can repair or at least get them in a reusable donatable state.*"

Unmaking as remediation. The topic of reducing environmental impact was also a key motivation for our experts in their practice. Lubari mentioned how it was only recently that he learned of how repair could connect to issues like global warning, but he now embraces connecting his work to reducing carbon emissions of e-waste. Hankerson expressed how "there's so much room for potential for us to utilize used stuff or use what we have." All approaches of upcycling or repairing devices meant reducing the amount of material that could potentially end up in a landfill. Similarly, promoting values of maintenance and buying secondhand meant reducing overall consumption of new devices that could potentially be wasted in the future too. However, remediation also came through in how our experts cared about modifying these devices so that they had added value. Hankerson discussed how servicing broken devices would both increase their value and longevity. Similarly, Honnet discussed how he actively resists planned obsolescence in repairing laptops: "you can spend a bit of money and you can actually make those laptops last decades." This also included producing added personal value through modifications. In discussing favorite examples of repurposed devices, striegl stated:

"I love all of these things where you take this safe, small, contained thing that is meant for this tiny purpose, and making it into something that seems really like full of its own personality and full of all this life. But I also like things that are projects where you take an old case, and you put a bunch of components into it, and suddenly you have cybertech. That's really cool. Like, you can take the screen out of something and take this keyboard from something else, and put them all together and make this really personalized, really customized thing for yourself. (...) I know a number of folks who have various mobility challenges, and so they customize their game controllers, so then they're very much their own and only work with their particular adaptive needs. That stuff is fantastic."

Unique materiality of e-waste. While working with new, pristine materials is often more straightforward than trying to work with material designated as waste, our experts often cited a lot of unique materials that they could only acquire through unmaking with e-waste or *because* it was considered e-waste. First, acquiring components via e-waste is often a cheaper means of getting components. In fact, Velasco often described her process of scavenging components by perusing the "free" section of Craiglist or riding her bike around the neighborhood on trash day so she could look at what was dumped on the streets before it got picked up. E-waste also could be a source of components that were not commonly available as consumer electronic trends shifted away from them. Velasco mentioned preferring to use switches or buttons from older devices because of their better quality and durability and striegl described seeking out variable transistors, potentiometers, or tungsten lamps which were hard to come by and had unique aesthetic or tactile qualities she preferred. Honnet also recalled when he turned to e-waste vendors to acquire the haptic motors Apple introduced in one of their iPhones before it was directly available to consumer markets: "*Apple doesn't allow you to buy spare parts except if you go through an official reseller at some point. (...) They were the first ones who were selling linear haptic actuators that were kind of affordable. (...) I started buying their haptic engine (...) you normally have to go through an official reseller but [the e-waste vendors] they had a whole building for this.*" Last, e-waste can be a means of finding components that due to supply chain issues, are not immediately available. Both Honnet and Lu described instances where they opted to choose components from e-waste vendors rather than wait for the long lead times from official electronic component vendors. And Honnet often finds how "hoarding" e-waste can be useful for always having components on hand. This quality was especially useful for a series of Honnet's projects designed to be accessible to build across various countries. When discussing the parts of this bike generator project, he explained, "*the idea was to try to replicate it as easily and cheaply as possible, so this came from a washing machine motor. Not all washing machines have that kind of motor but if you find one that has a DC motor, you can use it as a generator.*"

4.5 Cultures within Unmaking E-waste

The last dimension of unmaking e-waste we were interested in exploring with our experts was what cultures existed within unmaking e-waste. We use cultures in a very broad sense to encapsulate community values, associations, and emotions involved in unmaking e-waste. Moreover, we were interested in delving into how unmaking e-waste might differ across the varying contexts and backgrounds of our experts, especially in coming from different countries where policies around e-waste can drastically differ. We collected our findings in four themes: (1) mentalities of fear and lacking expertise, (2) visibilities and invisibilities of e-waste, (3) networks of e-waste, and (4) valuing repair and maintenance.

Mentalities of fear and lacking expertise. Usually, people initially feel very uncomfortable around taking apart e-waste or attempting to repair it. Our experts described how people often felt like they were not the right person or did not have the proper expertise to do these activities.

Velasco explained: *"I think that for a lot of people, they don't even consider it in the first place. People are just so used to the idea of that if something's broken, you can't fix it yourself that they don't even they don't even try (...) it would never occur to them to fix something yourself. Because a lot of products are designed [against that], manufacturers put those barriers in place on purpose. And then I think it's just a cultural thing that a lot of people like, are never exposed to feeling like they could that... I feel like a lot of its psychological."*

This also showed up in how people internalized (often gendered) notions of what a repairer looks like. When discussing the social environments of repair clubs, striegl explained how it can be an alienating experience: "you have to get over the barrier of it being the sort of stereotypical maker dudes, which is like old white men with beards and attitude, which is not a friendly place for a lot of people to be." Similarly, Lubari also recalled how he intentionally facilitated women in the settlement to feel empowered to do electronics repair. He explained: "*In our women in reuse and repair culture training, we first did an assessment to find out how women feel about repairing. And then we had put quite a number of items that they can choose to repair, and we realized most of them were going for tailoring like repair of textiles or the repair of shoes, but on bicycles and electronics, they fear like 'oh, we don't have the knowledge, right? We have not touched them.' And they feel that general repair that it's a work that can only be done by men. We had a two-day training, and then a one-day repair cafe event. It was basically for them to learn the basics. Learning about the tools for repairing, learning about how they can solder... And it was moving them, while they were learning. It was amazing them."*

In/Visibilities of e-waste. When describing e-waste, it would often oscillate between visible and invisible states. E-waste became extremely visible with the accumulation of discarded devices that could no longer be used. Choi described the normality of cycling through devices as a consumer and also periodically seeing the large number of devices wasted after art and technology programs concluded in his teaching roles. Honnet similarly recalls an NGO that cycles through laptops often donating to the hackerspace as otherwise, the laptops would just become trash. Lubari discussed how all the devices they work with come from the settlement themselves whether that is from personal devices of the refugees or generated by the organizations' offices. Hankerson described an overwhelming response when she started her business as every household had various forms of e-waste, often sitting in closets or garages collecting dust.

On the other hand, it was often more common for people to forget about e-waste or not see it as a priority. In Lubari's case, he discussed how the organizations that operated within the settlement did not see the issue of e-waste as a priority. Choi expressed concerns over the popularity of the smart cities concept as a "green" solution but not considering how likely they will be to generate large amounts of e-waste with planned obsolescence.

Relatedly, our experts described how it was often odd when electronics became defined as "e-waste." Lu described how what was considered e-waste has changed over time in China among e-waste vendors: "*In Shenzhen when you go to the market about three decades ago, they don't know what's e-waste. They just scale it. This one cost about maybe 100 Euro or US dollars, but per 100 kg. But now it's not [like that]. Now it's: I take this part if it's still valuable. They have a whole process to recycle used devices if this thing is valuable.*" This also came through in the ways that recycling policies were implemented. Choi described how in Korea: "*a really mind-boggling thing is that these agencies would collect smartphones, like old smartphones that are broken but in one piece, but they wouldn't take shattered away devices... I think it has to do with the way that profit is by counting how many devices that you collect.*" In this case, e-waste is defined by a "whole" device, neglecting services to a significant amount of devices that don't meet that criteria. In Hankerson's business, she is able to repair and resell 80%–90% of the devices that come through, showing how often e-waste does not have to stay as waste.

Networks of e-waste. Unmaking e-waste also involved interrogating the global networks beyond local experiences. This was important to Choi in thinking about e-waste generation and disposal in terms of colonialism. He explained, "*These days, it's actually kind of coming back as a form of e-waste, like a lot of the waste from Norway, Sweden, all those like green Scandinavian countries come to the Congo, or Philippines, or Indonesia. And they sell those things. And what's really messed up, it's that route of a colonial extraction to and then back to disposal [that] is actually very similar route as the telephone internet marine cables, like the transatlantic cables, slave trade route, that's all the same route.*" For him, e-waste becomes a way to critically explore the various relations of globalization, resource extraction, unethical labor practices, and visions of innovative technological projects that enable pollution and ecological harm, particularly in ways that benefit the markets of privileged countries through exploitation of others and the environment.

Additionally, our experts often brought up differences across countries in their methods for electronic waste management. For example, United States e-waste recycling regimes were contrasted with more robust material extraction and retrieval processes in Germany and the fines for improper e-waste disposal in Korea. Lubari lamented a lack of awareness and policy towards e-waste management, mentioning how open disposal was still allowed in South Sudan, but also noticed how repair cafes served a very different purpose compared to the ones his organization partners hosted in European countries as they needed to be multi-day long events rather than only a few hours. Honnet also often discussed how collaborators in Colombia and Indonesia were especially savvy in working with e-waste, noting how for many people recycling was "a full-time job." Similarly, Lu described how while in the Netherlands, she found that while they had good systems for sorting e-waste in bins to be picked up, it's not clear how they will approach recycling the various parts of a device. Meanwhile, in her experiences in China, she described how a common experience was having street cleaning ladies look through discarded e-waste and separate out materials that they could sell for money, usually as part of their income. She explained how even if you didn't separate the device, they would do the work of separating materials of the device because it could prove valuable for reselling. All these countries evolved many unique practices in unmaking e-waste that were highly situated and characterized by a mix of government policies, type of e-waste generated or imported, and their industries of reselling or recycling e-waste.

Valuing repair and maintenance. Finally, despite the importance of repair & maintenance, it is often undervalued work. Lubari describes: "*the perspective also in the refugee camp is that repair is basically for people who are not comfortable to continue with their education or people who have dropped out of school.*" Additionally, people have been taught to rely on manufacturers solutions for issues that often could be easily fixed through custom repairs. Lubari recalls: "*One time I was trying to talk to the organization [about] how we can minimize those wastes for example from the*

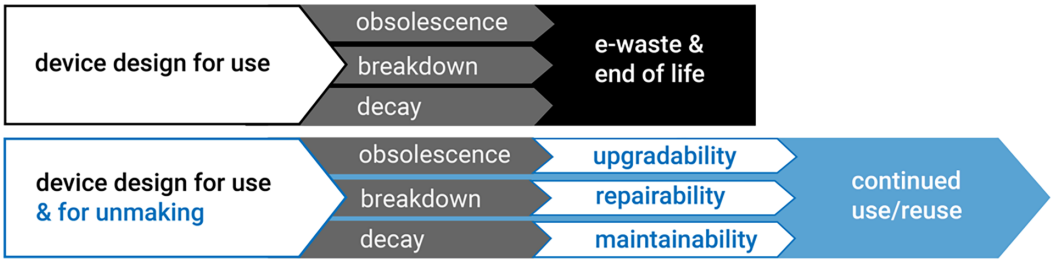

Fig. 2. We present two paths: (1) "device design for use" that ultimately usually ends up as e-waste through processes of obsolescence, breakdown and decay, and (2) "device design for use and for unmaking" that can withstand unmaking processes and afford for upgradability, repairability, and maintainability—enabling continued use/reuse.

printers. They buy printers and they don't take it for return sometimes and when its dead they keep it inside. But also the toner cartridges. They keep on buying new ones yet, that can be refilled. How come? We're like how do we support them?... but the challenge is that the organization have their policies where they do not allow them to contract us to repair them. So that is the biggest challenge with them, the lack of trust by those local organizations." In this case, the community repair work that Lubari offered could not be trusted over the printer companies' policies of selling new printer cartridges every time. Oftentimes, repair and maintenance work exist outside of the logics and priorities of companies developing consumer technologies, so much so that company policies can even actively discourage them with warranty policies or lack of repair support. However, the type of specialized knowledge repair technicians can extend to devices is extremely valuable. Lu describes marveling at repair technicians in an electronics market in Guangzhou when getting a camera fixed: "they actually bothered to help me to clean the mold inside the lens and then the guy was telling me how he can disassemble the whole lens and really careful cut the glass out and then clean and glue it back and then test it." This personalized attention & care for a device contrasts the normality buying and discarding devices. When electronics industries are more concerned with producing new gadgets, it becomes difficult to translate the value of this work.

5 Engaging Beyond "Use"

Drawing from the findings of our study, we reflect on how the HCI community can engage with and be inspired by the processes of unmaking e-waste. We are interested in how HCI can explore & design interactions with a device beyond "use"—beyond a device's intended functionality, particularly, in cases after they break down or are discarded. Similarly, we are interested in promoting the idea of humans not just as users but taking on alternative roles as recyclers, repairers, and re-users. In doing so, we see potential in unmaking e-waste for facilitating more circularity and extended lifetimes in our devices. We discuss this in four dimensions: (1) device design, (2) (re)user interactions, (3) (un)making tools, and (4) proximities to e-waste.

5.1 Device Design

Unmaking processes can better inform how devices get designed. In doing so, devices would be designed not just for use but also for eventual unmaking, anticipating obsolescence, breakdown, and decay, as depicted in Figure 2. Rather than design that resists unmaking processes, instead devices could be designed to welcome it.

In Section 4.2.1, the experts of our study discussed the effect of how devices were designed on their unmaking practices primarily in two ways: when leveraging the commonality of components

and when navigating planned obsolescence. In both cases, contemplating these characteristics becomes possible after taking a device apart and seeing its insides, understanding devices not just as black boxes but an assortment of different components. Doing so is counter to much of the ways we usually interact with devices—at its (surface-level) *interface*. But looking inside an e-waste device transforms a device's potential as a material rather than allow it to become wasted (or even recycled for raw materials). However, research has neglected focusing on device designs *for* their eventual unmaking.

As HCI is often concerned with building the next generation of technologies or how to facilitate "making" them, *we believe there is much research to be done on how to unmake them, especially with regard to enabling more sustainable hardware (e.g., reusing e-waste)*. We argue that researchers in HCI should design devices to support a second life beyond its initial intended usage and that support processes of repair & reuse. To those ends, approaching device design for use & for unmaking would require different methods than the traditional approaches that focus on user-centered, usability evaluation. Instead, device design for use & for unmaking also requires evaluation of upgradability, repairability, and maintainability. Through our findings, we outline questions that can be used to interrogate a device design for unmaking:

(1) *Upgradability*—Can upgrades (i.e., new features, add-ons, swappable modules) be made without the complete replacement of the device and while generating minimal waste? If obsolescence occurs, will the device be able to function? How does the device's design anticipate upgrades rather than resist them?
(2) *Repairability*—In the event of decay or breakdown, how easy is it to repair the device? How accessible are repairs to the average person? What sort of services do they need to engage with for repair? Is diagnosing issues of decay or breakdown possible? How does the device's design encourage repairs over buying anew?
(3) *Maintainability*—Is the device built in a way that anticipates longevity of use? How does it design for parts that will need to be serviced more regularly to ensure longevity? Is the lifetime of device use constrained by the shortest lifetime part (i.e., batteries)? Will servicing the device still be possible if official company parts and boards are no longer available?

5.2 (Re)user Interactions

Our experts discussed a wide variety of user interactions that are not traditionally the focus of HCI research. HCI has a rich history of being concerned with expanding the notions of who a "user" can be, particularly to push back against oppressive norms and incorporate diverse identities across race, gender, and disability. Work by Baumer and Brubaker goes even further in critiquing how normative representations of what a "user" is can both empower and constrain the scopes of interaction we explore in our HCI research, inviting researchers to examine the relationships that are often under-accounted for and considering what HCI looks like in the absence of a user [6]. We draw from this concept of post-user interactions and consider how unmaking e-waste troubles the traditional "user" that HCI designs for. As shown by our expert's work, users of devices extend beyond the original consumer and can also include additional "users" such as secondhand users, repairers, or upcyclers. Only conceiving users through the role of a singular user who eventually discards a device discloses the potential of a device beyond its primary use. In fact, our experts provided many instances of devices having second lives even after becoming e-waste: being repaired and resold or dismantled and incorporated into new forms. As such the potential of e-waste devices often extends beyond what initial users might conceive as possible, only being realized through unmaking interactions by additional "users" as shown in Figure 3.

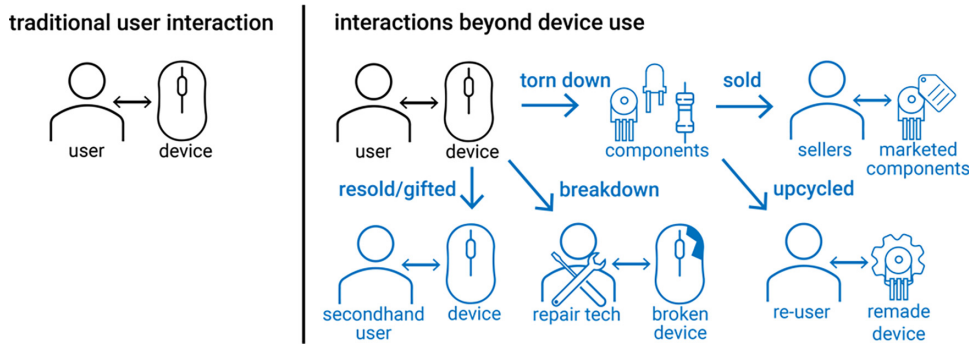

Fig. 3. Whereas traditional user interactions look only at a single user-device configurations, considering interactions beyond device use allow for engagements with many other configurations after events like breakdown, teardowns, reselling, and upcycling.

Also, while the issue of e-waste should not be seen solely as a post-consumer problem, the act of discarding a device is also a user interaction worth considering. Our experts often discussed frustrations around others' abilities to carelessly throwaway seemingly pristine devices, but they also acknowledge the conditions that make such practices possible: inaccessible or expensive repair services, cheaply made consumer electronics or the discomfort around unmaking e-waste itself (Sections 4.4 and 4.5). Previous HCI work has explored why somethings get discarded and developed theories about attachment with our things, primarily imagining how such values could be transferred to interaction design [22, 48]. Similarly, interactive techniques could be developed that center around teaching skills of reuse, repurposing, or repair. The HCI community historically has shepherded many new interaction techniques and perhaps interactions around unmaking could be pursued after widening our concept of what user interactions could mean.

5.3 (Un)making Tools

In unmaking e-waste, our experts described how their practices would diverge from traditional "making" tools or even what is typically seen as traditional "making" education. In Sections 4.1 and 4.2, we highlight the various benefits in learning through unmaking e-waste as it promoted creative problem solving, empowered people to understand how their devices worked, and allowed people to use unmaking e-waste as an entry point into understanding broader electronics manufacturing infrastructure. These experiences show how there is a lot of potential into finding ways to incorporating "unmaking" into "making" tools & education. Just as HCI has been active in researching how to better teach engineering principles through domain-knowledge editors, toolkits, games, and tutorials, there is a wealth of research that could be oriented around unmaking tools/education for recycle, repair or reuse [42, 44, 46]. Whereas most maker education builds from the ground up, configuring materials together to produce a final object. Unmaking e-waste (or unmaking education more broadly) could start from the object and take it apart, offering an initial context for its components and then inviting creative thinking about what new contexts these components could exist in. This is most clearly argued by striegl in Section 4.4, where she discusses how taking things apart widens the potential of what things could be as opposed to standard maker toolkits guiding projects on a singular path.

Pursuing unmaking education alongside making education also encourages a revaluation of repair and reuse skills. As discussed by our experts, these practices often aren't seen as high-skilled labor even though they are extremely technical processes and require developed expertise. Why

are repair and reuse skills not a more central part to engineering or making education in the first place? When starting with an understanding that unmaking is an inevitable occurrence, it seems odd that these practices are not paired alongside making.

At the same time, supporting unmaking education requires different resources and skills to be taught compared to making and, as our experts discussed, a significant barrier to unmaking is the fear around taking objects apart. Additionally, in imagining what would make unmaking devices easier for our participants, our experts made several recommendations: centralized resources on unmaking electronics, making repairs visible for the next repairer, and manufacturer support & documentation. The development of unmaking education aligns with HCI's values, but it may conflict with industries' goals of keeping their designs proprietary—this tension remains an open research challenge.

5.4 Proximities to E-waste

Throughout our conversations each participant felt they could engage with the issue of e-waste whether that was through education, their business, or even just for fun. Moreover, our experts were moved to begin their practices for unmaking e-waste because of more abstract notions of reducing environmental impact, but they were also moved by the ability to provide care and maintenance to devices on a personal level (Sections 4.1 and 4.4). On the other hand, our experts expressed how unmaking e-waste broadened the scope of the issue of e-waste, as it could be resold as secondhand devices, end up as scrap in the Chinese e-waste marketplace, or in e-waste dumps in "third world" countries. E-waste is made, unmade, and made again by its incredibly global and far-reaching networks of exchange, with impacts of device use beyond our immediate interactions with them. However, as far-reaching as the issue of e-waste is, it also remains very personal and local. As one of our experts argued, everyone has a direct connection to e-waste, so it becomes a common starting point for talking through these complex relations that enable this e-waste paradigm.

Similarly, HCI practitioners should embrace their proximities to e-waste at various levels. As argued before, this could target the personal use of devices, encouraging practices of care and maintenance or responsible disposal. This could also be at the organizational or community level, examining how our technological infrastructure gets wasted. More broadly, the policies of governance around e-waste can also be interrogated. These include the issues brought up by our experts around the wasteful processing of e-waste by some recycling facilities, how accessible responsible e-waste disposal is to the average consumer, or right to repair and lack of accessible repair services. As a community of scholars, just as we have been able to advocate for fair and responsible technologies in other areas, perhaps we can be advocates of better solutions to e-waste.

Last, on a global level, e-waste reveals how interconnected our technological devices truly are. As a global community that is increasingly invested in advancing computing research that is less WEIRD,[1] properly acknowledging these relationships as deeply intertwined and inextricable may allow us to acknowledge the impacts of our technology more fully (as opposed to believing that e-waste is an issue of elsewhere). In addition to user interfaces and device design, HCI has a responsibility to attend to the larger systems, industries, and infrastructures that allow for technological innovation [7, 13, 30]. E-waste is a clear physical manifestation to how technological "progress" can produce harms that are often unequally shared; more directly confronting this fact should be a priority of the community. HCI is both a shaping force to technological innovation and a global community that is concerned with how technologies are shaping our world. If HCI does not engage with e-waste, then who else will?

[1]WEIRD—Western, Educated, Industrialized, Rich, Democratic.

6 Conclusions

In this work, we present an analysis of the pathways, processes, motivations, challenges, and cultures of various experts who engaged in practices of unmaking e-waste. Such discussions allowed us to synthesize learnings to identify specific research topics the HCI community is particularly well-suited to explore.

6.1 Framing Our Findings

Our work contributes to a growing body of literature around addressing the issue of e-waste. Previous work has identified similar findings in processes of reusing or repairing e-waste, particularly in employing crafty approaches to working with the material [26, 35, 42, 44, 55]. However, our experts also offered unique perspectives previously not well-covered by HCI literature on e-waste, particularly with Lubari, Lu, and Choi, who spoke to evolving e-waste practices in non-WEIRD countries. Notably, experiences on unmaking e-waste are highly dynamic with constantly evolving practices, e-waste recycling policies, and commonly generated e-waste (due to variations in electronic design trends). Thus, it was important to us to highlight our expert's unique experiences and reflections on unmaking e-waste rather than extrapolate how they generalize to broader unmaking e-waste practices.

6.2 Limitations and Future Work

E-waste is a complex and highly contextual issue. The ways that people interact with e-waste differ dramatically across the world. Additionally, the issue of e-waste is highly informed and influenced by media coverage [64]. And while some of our experts highlight experiences with e-waste in non-WEIRD countries, the majority live and work in WEIRD countries or are affiliated with organizations from WEIRD countries. Thus, we do not attempt to present our work as encapsulating all ways of unmaking e-waste. Moreover, a more focused study on experts of more similar backgrounds and practices (e.g., repair technicians) might reveal different findings. Similarly, we do not focus on people with expertise in urban mining recycling. We were more interested in the crafty, hands-on approaches to unmaking e-waste, but the perspective of recycling could also enable valuable insights. Additionally, while not focused on in our work, grey market components that often appear from e-waste reselling (generally affiliated to Chinese e-waste marketplaces) and challenges of regulating or guaranteeing quality was also often discussed in our interviews. More work remains in examining the relationship of these grey markets to e-waste and their resulting effects on repair and reuse industries.

We also acknowledge that while we present our work as a means of contending with the issue of e-waste and offer unmaking e-waste practices for reducing e-waste, empowering consumers only supports reductions in a much smaller sliver of e-waste generations compared to manufacturing sources. In HCI, we most often deal with users and discuss interactions at an individual level. The same is true for our work in highlighting the experiences of individuals. While we believe engaging with e-waste on this level might not be quantitatively impactful compared to diversions in other areas, it can be meaningful for users and how they think about their relationships to technology.

Ultimately, we feel that the question of e-waste is a question of HCI too. How we contend with getting to a point of producing millions of tons of e-waste per year and how we plan to move forward are questions the community should be struggling with. While waste and waste management may not feel like an HCI issue, how "computers" become waste and what users do with these devices is a deeply HCI issue. In this work, we attempted to elucidate how unmaking e-waste is directly aligned with the research agendas of the HCI community. We hope that others can be similarly inspired to develop new engagements with e-waste in their work.

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