Insights from an ICT4D Initiative in Kenya’s Immunization Program: Designing for the Emergence of Sociomaterial Practices

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Insights from an ICT4D Initiative in Kenya’s Immunization Program: Designing for the Emergence of Sociomaterial Practices

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Abstract:

ICT4D initiatives hold the potential to transform health service delivery in settings of poverty, yet, in practice, they face many of the same implementation complexities and coordination challenges as the global health and development programs that they aim to streamline or strengthen. Researchers and practitioners alike are now quick to observe that “context matters”, but such an observation does not amount to a coherent alternative vision of more appropriate ICT4D design and implementation. In this paper, we draw on the metaphor of imbrication to elucidate the iterative process by which ICTs become entangled with particular contexts of use. Our longitudinal ethnographic study examines the implementation and iterative redesign of an Internet of things (IoT) technology that collects real-time data and alerts health workers of disruptions in the cold storage of vaccines in Kenya. Extending recent work on imbrication, we show that technologies imbricate not only with the social context but also with local material infrastructure and that designers play a limited yet clearly consequential role in this process. To explain these findings, we highlight instances of material “back talk” and concomitant practice breakdown in which initial attempts to shape a situation yield puzzling or unappreciated consequences, which lead designers to accommodate material realities and, ultimately, pursue unanticipated courses of action. Drawing on these conceptual tools, we reveal six overlapping activities through which designers may guide the emergence of sociomaterial practices. We say that they design for the emergence of sociomaterial practices to underscore that designers cannot predict or control all contextual complexities, though they can adapt to them when they arise. Based on our insights about this process, we develop three contributions. First, we offer fresh perspective on the longstanding concern with local context in ICT4D research. Second, we suggest that our notion of designing for the emergence of sociomaterial practices is relevant for and adds to contextually aware design research frameworks such as action design research. Finally, we propose that ICT4D practitioners should attend to practice breakdowns and material back talk as they grapple with the complexities of the implementation bottleneck in global health and development.

Keywords: Action Design Research, Digital Health, Global Health Implementation Research, Human-centered Design, Health Information Systems, ICT4D, Immunization, Internet of Things, M-health.

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1 Introduction

Vaccines are among the more cost-effective health interventions ever developed, and alliances of international donors supply national immunization programs in poorer countries with vaccines to cover their populations. Nonetheless, approximately 1.5 million children died of vaccine-preventable diseases in 2011 (Gates Foundation, 2014). Shortfalls in routine immunization illustrate what some have termed the implementation bottleneck: the growing global burden of illness attributed to inadequacies in delivering treatments that are well known to be effective and affordable (Kim, Farmer, & Porter, 2013). The interrelatedness of human health and development means that this implementation gap concerns not only health systems but also sustainable development at large. Following Sahay (2016) and others, we take the view that health is development because it correlates with prosperity (World Bank, 1993), and health equity is an important aspiration in its own right (Qureshi, 2016).

Digital health and, in particular, mobile health (or mHealth) interventions have featured prominently in global health delivery efforts. As one World Health Organization report put it, “mHealth has the potential to transform the face of health service delivery across the globe” (Kay, Santos, & Takane, 2011 p.1). Yet, in practice, these digital technology initiatives face much the same implementation complexities and cross-cutting coordination challenges as the global health and development programs that they aim to streamline or strengthen. The proliferation of small mHealth and information and communication technology for development (ICT4D) pilots has become so severe that many bemoan a widespread “pilotitis” as if the failure to cultivate scalable interventions or reproduce successes in development or humanitarian contexts were a kind of disease (Shuchman, 2014; Tomlinson, Rotheram-Borus, Swartz & Tsai, 2013).

Practitioners and researchers alike now embrace the dictum “context matters”. Yet, this dictum does not amount to a coherent alternative vision of more appropriate ICT4D design and implementation. In an important step towards such a coherent alternative, the Principles for Digital Development consensus statement1 urges practitioners to embrace guidelines such as “design with the user”, “employ a ‘systems’ approach to design”, “develop projects in an incremental and iterative manner”, and “work across sector silos to create coordinated and more holistic approaches”. Many authoritative global health and development institutions, such as the US Agency for International Development, The Bill and Melinda Gates Foundation, and several United Nations agencies, have endorsed the statement. The shift in emphasis from ICTs that support service delivery to principles for designing ICTs effectively is substantive because it recognizes the opportunities of ICT4D without attributing impact narrowly to discrete technologies. However, widespread lack of clarity remains about how to put these design principles into practice in global development programs characterized by emergent complexity, ambiguity, poor coordination, and rapid change (Waugaman, 2016).

In this paper, we explore how the information systems (IS) discipline might address such design and implementation challenges in ICT4D. We draw on the metaphor of imbrication (Ciborra, 2006; Leonardi, 2011) to elucidate the iterative process by which ICTs become entangled with particular contexts of use. We find the imbrication metaphor useful because it suggests a gradual intertwining of social and material elements to produce sociomaterial practices. While technologies can travel across contexts, the notion of ICT4D interventions as sociomaterial practices (Orlikowski, 2007) implies a more holistic view in which material objects and contextually situated human activities are both integral to the ongoing performance of ICT4D initiatives. Thus, we can trace how ICT4D interventions emerge without resorting to deterministic language about the impacts of either technology or human aims. Following Leonardi’s (2013, p. 71) call, we specifically elucidate how and why imbrication occurs, how material artifacts are imbricated with particular local contexts, and why sociomaterial practices emerge with a certain form and not otherwise. We were particularly interested in how a developing country context might shed light on aspects of this process that would be less apparent in the North American and European contexts of most information systems research.

To this end, we undertook a longitudinal ethnographic study of an ICT4D initiative that aimed to improve immunization services in Kenya. Our paper builds on 88 days of fieldwork, audio recordings, and notes from 106 interviews and over 3,200 photographs. We document the implementation and iterative redesign of TempTracker, an Internet of things (IoT) prototype that uses remote temperature-sensors to collect real-time data and sends SMS text messages to alert health workers of disruptions in the cold storage of vaccines. This initiative sought to improve the coordination of the vaccine cold chain at rural health facilities in Kenya and, thereby, ensure the safety and effectiveness of temperature-sensitive vaccines.

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1 Principles for Digital Development (see http://digitalprinciples.org)
Prior work on the process of imbrication has emphasized that technology users may perceive the materiality of ICT artifacts as either constraining or as affording new capacities for action and may choose to reshape either technology or routines accordingly (Leonardi, 2011). While a helpful starting point, this framework did not map well to some of our fieldwork experiences or to the perspective of technology designers with whom we worked throughout this study. We found that we could not easily attribute some important turns in the design process to subjective user perceptions, that technologies imbricate not only with the social context but also with local material infrastructure, and that designers play a limited yet clearly consequential role in this process.

To explain these findings, we draw on the notions of material “back-talk” (Schön, 1983; Yanow & Tsoukas, 2009) and concomitant practice breakdown (Winograd & Flores 1986; Yanow & Tsoukas, 2009). In this perspective on design, initial attempts to shape a situation often yield puzzling or unappreciated consequences, which leads designers to accommodate material realities and, ultimately, pursue unanticipated courses of action. Drawing on these conceptual tools, we reveal six overlapping activities through which designers may guide the emergence of sociomaterial practices. We say that they design for the emergence of sociomaterial practices rather than suggesting that they design sociomaterial practices to underscore that designers cannot predict or control all of the contextual complexities that inevitably arise when people begin using new technologies. However, designers can respond to such complexities and thereby guide the emergence of new practices.

Based on our insights about this process, we develop three contributions. First, we offer further insight into the longstanding concern with local context in ICT4D research. We emphasize how technologies imbricate with a range of local materials and highlight how features of a social context become integral to the interventions that ICT4D practitioners document in user guides and hope to scale to other settings. Second, we relate our findings from ICT4D design and implementation in Kenya to IS design more generally, and, in particular, we reconsider how recent work on imbrication has treated the agency of designers. We also explore the relevance of our notion of guiding the emergence of sociomaterial practices for contextually aware approaches to design research such as action design research (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). Finally, we discuss how attention to practice breakdowns and material back talk might equip ICT4D practitioners to grapple with the many complexities that characterize the implementation bottleneck in global health and development.

2 Imbrication of Human and Material Agencies

Leonardi (2011) uses the metaphor of imbrication to describe how human and material agencies intertwine to produce sociomaterial practices. This metaphor refers to ceramic roof tiles (the imbrex and tegulae) in ancient Greece which suggests an arrangement in which two distinct kinds of elements interlock and function interdependently as a single unit. However, other authors have emphasized that the metaphor need not necessarily evoke predictable grid-like orderliness:

Far from keeping distinct these two representation domains, the human and the non-human, we are going to show the ramifications of an unfolding imbroglio (Latour, 1999) for which the word “network” turns out to be too Cartesian and tidy. The concept of imbrication better captures the reciprocal, self reinforcing, often non-linear, impacts of one representation upon the other. (Ciborra, 2006, p. 1340)

Following Leonardi (2011, 2012, 2013), we suggest three noteworthy advantages of the imbrication metaphor. First, it allows one to assert that human and material agencies are both integral to the performance of sociomaterial practices and, thus, the shaping of ICT4D initiatives yet acknowledge that human agency is distinct with respect to intentionality and the capacity to plan and organize around goals. In this view, materiality refers to how “physical and/or digital materials are arranged into particular forms that endure across differences in place and time” (Leonardi, 2012, p. 7). While the term materiality speaks to what an ICT artifact or some other object is, the notion of material agency refers to what materiality does in a particular situation. Rather than taking certain technical capacities for granted in light of an object’s inherent materiality, a performative perspective on material agency means documenting how particular material objects actually function or perform in the here and now of some particular practice.

Second, the metaphor of imbrication draws our attention to the relative path dependency or staying power of practices. As Leonardi (2011 p. 151) puts it, “because the metaphor of imbrication sensitizes us to the production of durable patterns, it reminds us that all interactions between human and material agencies produce an organizational residue”. Over time, this residue may fade into the background of
organizational life; people may “black box” their practices in the sense that they no longer question why ongoing routines came to intersect with technologies in particular ways.

The notion that imbrications in the here and now are inevitably shaped by prior imbrications brings us to our final point: the importance of writing about cumulative changes without resorting to deterministic language. To *imbricate* is a verb, and the metaphor suggests a dynamic process that unfolds with the passage of time. As the growing literature on imbrication documents, the particular manner in which human activity and materiality imbricate at some particular point in time will inevitably be influenced by current practices, which were shaped by imbrications at prior points in time. In this way, we can write about a particular point in time at which a new IT artifact is introduced in an organization, while acknowledging that workers are always already immersed in prior imbrications of social activity and materiality. This perspective places materiality analytically front and center and recognizes that the materiality of an artifact bounds the range of viable perceptions.

With this sense of gradual accumulation, researchers face the challenge of elucidating why the process of imbrication unfolds as it does and not otherwise. That is to say, “an imbrication perspective must provide a language to explain how activities in the past condition, (as opposed to cause) future human–material sequencing” (Leonardi, 2011, p. 152). While a helpful starting point, existing work on imbrication has appeared to grant technology users a dominant role in that their perceptions of materiality led to collective choices about how human and material agencies would imbricate. This work has not wholly explained some of our fieldwork experiences or the perspective of technology designers with whom we worked throughout this study. When we followed TempTracker devices from a lab in California, where they had performed well, to a health system in rural Kenya, we encountered various kinds of difficulties that we could not easily explain as stemming from users’ perceptions of materiality. Iterative improvements to devices were made to not only accommodate the perceptions of technology users but also the objective conditions in which the process of imbrication was unfolding, and the perceptions of designers were consequential in this process. To explain these observations in reference to our empirical case, we review related work on practice breakdown and material back talk in Section 3.

### 3 Material Back Talk and Practice Breakdown as Catalysts for Imbrication

In exploring critical realism as a philosophical foundation for studying sociomaterial practices, Leonardi (2013) argues that emphasizing people’s socially constructed conceptions is entirely compatible with granting some objective reality to “the world out there”. Leonardi cites Herbert Blumer to argue that such a perspective may be achieved by integrating an empirical constructivism with an ontological realism:

> The empirical necessarily exists always in the form of human pictures and conceptions of it. However, this does not shift “reality”, as so many conclude, from the empirical world to the realm of imagery and conception.... [This] position is untenable because the empirical world can “talk back” to our pictures of it or assertions about it—talk back in the sense of challenging and resisting, or not bending to, our images or conceptions of it. (Blumer, 1969, p. 22, quoted in Leonardi, 2013, p. 68)

In this vein, our analysis draws on Schön’s (1983) work on reflective practice and *design as a conversation with materials*, which Bannon and Ehn (2013) note is a mainstay of many design frameworks. This work is heavily influenced by the pragmatist philosophy of John Dewey (2005, 2013) for whom framing situations, experimenting, and learning-by-doing are central. In this view, design work is so complex that implementing a prototype or attempting to shape a situation typically yields intended and unintended consequences. Designers make an initial “move” and the situation often “talks back” in the form of puzzling or unappreciated consequences. If the designers allow themselves to perceive this back talk, they may respond with an alternative move, an emergent course of action.

In this sense, feedback offered by a cognitively reflecting human speaker differs substantially from *material back talk*, which emerges spontaneously where human actors (e.g., technology end users) and non-human actors (e.g., prototypes, infrastructure, a particular office space) come into relation with...

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2 A genealogy of the notion of back talk is beyond our scope here, but it bears mentioning that the similarities between Blumer’s and Schön’s uses of the term are not coincidental. The connection is that Blumer’s symbolic interactionism and Schön’s reflective practice both bear the influence of the classical pragmatist philosophers for whom experiences of trouble, disruption, or back talk were vital catalysts and pre-conditions for directed problem solving and, ultimately, intelligence and creativity.
unforeseen consequences (Yanow & Tsoukas, 2009). The understanding that material back talk emerges from beyond the realm of human agency is vital for the perspective that designing in this manner involves something more than implementing subjective tastes or preferences. To call it a conversation with materials suggests an active and probing kind of situated inquiry. Insofar as it addresses instances of back talk that were real and consequential, it may exhibit a kind of rigor in dealing with highly situated or contextual complexities. Schön (1983, p. 42) argues that such a view of rigor is important if we are to transcend the dilemmas of rigor or relevance that so often play out in situations of great complexity, uncertainty, instability, uniqueness, or conflicting priorities.

Winograd and Flores (1986) highlight how technology design may advance through responses to “practice breakdowns”, and while their work bears some similarities to Schön’s discussion of back talk, two differences are salient to our analysis. First, Winograd and Flores draw on Heideggerian phenomenology (Heidegger, 1996) to explain the routinized and unreflective nature of ordinary practices (a state which they call absorbed coping) and the phenomenal experience of surprise, puzzlement, and reflection that practice breakdown may engender. Second, they incorporate a language as action perspective and treat “language as the primary dimension of human cooperative activity” (Winograd, 1986, p. 203). While the former point is well suited to our analysis, the latter point is less well suited to recognizing materiality and the processes of imbrication through which human and material agencies intertwine.

To draw on Winograd and Flores’ (1986) insightful analysis of practice breakdown while retaining Schön’s perspective on the significance of material back talk, we consider Yanow and ’Tsoukas’ (2009) recent phenomenological re-reading of Schön’s work. In their analysis, practice breakdown is not only a matter of social or human relations; it can also stem from concrete encounters with material back talk. Recasting Schön’s work in Heideggerian terms (Dreyfus, 1991; Heidegger, 1996), they emphasize material back talk while further delineating degrees of practice breakdown. This framework is helpful because it emphasizes that encounters with back talk may engender a range of experiences that disrupt our ordinary unreflective coping. Before total disruption, back talk may engender experiences of annoyance, doubt or discomfort, spontaneous workarounds, or even reflective planning with respect to how technologies may be used differently. When technology users experience more mild and temporary breakdowns, technology designers do not always take notice, particularly in ICT4D initiatives in which designers are often far removed from users. Even when designers notice more subtle forms of breakdown, they will not always interpret them as generative opportunities for iteration (i.e., as opportunities to proactively reconfigure technologies or routines). Rather, seeing a particular breakdown as an annoyance or as an opportunity for iteration is a matter of judgment in which designers exercise considerable agency, which our findings below illustrate.

4 Research Site and Methods

We draw on participant observation and interviews that the first author conducted during three rounds of fieldwork in Kenya’s rural Mavueni District that lasted a combined 88 days from early 2013 to late 2014. Specifically, the first author conducted roughly six weeks of fieldwork from March to May, 2013, during an initial eight-facility pilot; three weeks of fieldwork in April, 2014, as nurses at more than forty facilities were trained to use the device; and a final four weeks of fieldwork in November and December, 2014, as the initiative concluded. In addition to extensive observational and reflective field notes, the data include over 3,200 photographs and videos, audio recordings and notes from 106 interviews, 74 project documents, 658 email exchanges, and meetings conducted via Skype. Before undertaking the fieldwork for this study, the first author had visited Mavueni on four prior occasions and had resided in the region from mid-2009 until mid-2012 during which time designing and implementing global health technologies was his primary occupation. Prior familiarity with the region, the Mavueni District Ministry of Health, and with Medic Mobile facilitated impeccable access. We analyzed data with an insider-outsider, iterative process of grounded coding, visual mapping, and comparison with existing frameworks.

4.1 Case Selection

Our approach to selecting a case was influenced by Walsham’s (2012) advice that research may be more interesting and even inspiring if one studies how practitioners use ICTs to make a better world and to critically analyze who benefits and who misses out. Routine immunization programs present deeply
important opportunities for studying the global health implementation bottleneck and the complexities of using ICTs to address this bottleneck.

Moreover, Kenya is a highly suitable setting for studying such challenges. In rural Kenya, one cannot assume that trained staff will be present during a health clinic’s “open” hours; that maintenance workers will not be called on to act as nurses or vice versa; or that medical equipment, telephones, electricity, plumbing, vehicles and roads will function reliably. Public sector health workers rely on support from myriad (typically transient) international development funders and practitioners, which can further disrupt common understandings of task priority and feasibility, make work schedules less predictable, and complicate efforts to clarify who will account for particular tasks. Too often, short pilots and standalone projects are organized in disease-centric silos, which further fragments service delivery.

We selected to study the TempTracker initiative in part because the Bill and Melinda Gates Foundation’s much-discussed grand challenges funding scheme funded it through a grant to the non-profit organization Nexleaf Analytics. Nexleaf had made plans to partner with Medic Mobile, and we first heard about the initiative through the first author’s contacts at Medic Mobile. While we were interested in participating in the design process, we opted for participant observation rather than an overarching design research framework such as action design research (Sein et al., 2011) in part because we were not in a position to establish the terms or timelines of the design process. However, the first author’s prior familiarity with local culture and language and his contacts at Medic Mobile and at the Mavueni Ministry of Health facilitated unusually strong access. Therefore, we could build a richly detailed case in a relatively challenging research environment in a nonetheless realistic manner (Miles & Huberman, 1994).

Finally, as Barrett, Davidson, Prabhu and Vargo (2015) observe, settings such as Kenya afford IS researchers many opportunities to extend existing theories because such settings have such different economic and institutional structures. With that said, we do not suggest that findings from low-income settings are so different as to be irrelevant to wealthier settings. Rather, we can understand them as what Pettigrew (1990) calls extreme cases in that they throw into sharp relief dynamics that may be less readily observable but also at play in other situations.

4.2 Empirical Context: Conferring Immunity, Delivering Potent Vaccines

Vaccination programs confer immunity by exposing human immune systems to pathogenic organisms (e.g., viruses) that have been modified so that they do not cause harm. Immune systems learn to recognize the harmless pathogens, and, as a result, they can more effectively recognize and combat future infections of the wild pathogen. An important ramification of using biological materials to confer immunity is that they rot when left at room temperature and decompose even faster when frozen; as a result, they lose their structure and, thus, their potency. Despite extensive research and development efforts, temperature-insensitive vaccines remain elusive, and the necessity of cold storage at 2-8°C continues to shape the work of conferring immunity worldwide.

Immunization programs accommodate the 2-8°C temperature range through a variety of cold storage practices often referred to as the cold chain. At rural clinics in Mavueni, the cold chain includes equipment such as refrigerators and thermometers and infrastructure such as grid electricity, solar panels, and propane to power fridges in lieu of grid electricity (see Figures A1 and A2). It also includes stock ledgers, paper charts, and other information tools with which workers and their supervisors track cold chain equipment and activities. Nurses are expected to visually check thermometers twice daily and to record temperatures on paper temperature charts. In practice, overworked nurses often delegate the task to data clerks, security guards, and other casual laborers with little or no formal medical training. Sometimes, no one performs the task at all, particularly at the numerous facilities with just one or two nurses, which the blank fields on temperature charts that we observed when visiting clinics evidence (see Figures A3 and A4).

Managers are quick to remark that nurses face extenuating circumstances. Not only is the cold chain just one aspect of immunization; immunization in general is often sidelined as patients arrive with more urgent concerns such as broken bones, acute infections, or to give birth (see Figure A5). However understandable these deviations from the protocol may be, some have expressed concern that the gap between official tasks and daily cold chain activities causes recurring outbreaks of vaccine-preventable diseases such as measles and meningitis. As one manager put it:

*When we get an outbreak, then we are looking in the program, was it the coverage? Is it people migrating to our region who were not vaccinated? Is it that the program at a time, there was a*
break down in that people received impotent vaccines? We all look at that, so that at any given time you want to see exactly, what was the gap?

4.3 The TempTracker Initiative

From late 2012 to late 2014, the Mavueni Ministry of Health worked with two international charities, Medic Mobile and Nexleaf, to pilot a prototype remote temperature-sensing device called TempTracker for monitoring refrigerators that store vaccines at rural health facilities.

Nexleaf is located in California and their primary expertise lies in developing remote sensing technologies for a variety of applications in global health and international development. Medic Mobile designs and implements open source technologies for global health and has worked in more than 20 countries from offices in Nairobi, Kathmandu, and San Francisco. Both organizations are relatively small with fewer than a dozen (Nexleaf) and approximately 60 (Medic Mobile) staff. Nexleaf had product-development responsibilities, which included developing a functional prototype temperature sensor, “bench-top validating” the prototype in California, and implementing iterative improvements based on field-testing abroad. In contrast, Medic Mobile had design-oriented responsibilities, including selecting a pilot location, training health workers, and making recommendations to iteratively redesign the prototypes based on ongoing observation of TempTracker use and the broader work context.

Nexleaf designed TempTracker to automatically measure and submit temperature data via mobile Internet and to send text message alerts whenever fridges reach temperatures that could damage vaccines. The initial prototype comprised a four-foot long cord with a temperature sensor on one end and a typical audio jack that plugs into the headphone socket of an Android smartphone on the other end. The smartphone sat inside a generic box of hard plastic from which ran another cord that connected the smartphone to a typical electrical socket (see Figures A6 and A7). Installed on the Android phone’s operating system was a custom TempTracker “app” for syncing temperature data to a Web server via mobile Internet and sending SMS text message alerts via the mobile phone network. Broadly speaking, the TempTracker program sought to improve coordination in the vaccine supply chain and, thereby, maintain vaccine potency and improve population health. In particular, the program sought to provide health facility staff and “frontline managers” with real-time data and monthly aggregate reports so that they could mount more timely and effective responses to cold chain disruptions.

A pilot at eight clinics began that focused on iteratively redesigning the prototype devices while also refining training, maintenance, and other related activities to improve and ultimately validate the approach “in the field”. Medic Mobile selected the Mavueni district in rural Kenya as a pilot location in part because it had a prior working relationship with the Ministry of Health and in part because the difficulties of providing healthcare in Mavueni were similar to those faced in many rural settings of poverty. While the Ministry of Health fully owned most of the clinics in the district, individuals, churches, or international charities owned and operated about one in four. The Ministry of Health provided these private organizations with vaccines and, in most cases, with fridges free of charge. In turn, their immunization activities were subject to standard ministry reporting and supervision.

Some clinics were just kilometers away from the district office, while others took hours to reach over rutted dirt roads that often became impassable during the rainy season (see Figure A8). Further, electricity outages, staffing shortages, and sporadic lack of funds to fuel the vehicles that would transport district staff to rural facilities for routine supervision or equipment maintenance and replacement complicated efforts to maintain the vaccine cold chain.

During the course of this study, stock outs of vaccines and essential medicines and health worker strikes related to delays in promised raises and disbursements of salaries and general operating budgets for clinics disrupted health services in the region. Some of these disruptions were related to the broader sociopolitical context, including ongoing terrorist attacks (Bremmer, 2015), the threat of post-election violence in 2013 (BBC, 2013), and devolution of health sector governance from the national to the county level (the result of constitutional amendments that followed post-election violence in 2007) (BBC, 2012). All international workers (including the first author) experienced gastrointestinal ailments, one was hospitalized for severe dehydration secondary to food poisoning, and one of the Kenyan TempTracker users died of tuberculosis.

These challenges were more destabilizing than those that face most innovation teams in wealthier countries. And yet, advocates of global health equity argue that technology and innovation stand to be of the greatest benefit to humanity in precisely these kinds of settings.
4.4 Data Collection

Data collection followed common recommendations for ethnographic research (Spradley, 1980; Van Maanen, 1979, 1988): participant observation and informal conversations complemented by document analysis, formal interviews, and focus groups. True to the ethnographic tradition, the first author was fully immersed during fieldwork, which included sharing accommodations and most meals with other members of the TempTracker team. He joined the project team in visiting rural clinics, training health workers to use TempTracker, returning to clinics to provide technical support and investigate devices that did not upload data to the online dashboard, discussing ongoing design issues with engineers in California, and reviewing the project with managers at the Ministry of Health. He extensively photographed these activities (of over 3,200 photographs, about 800 are of temperature charts and other cold chain reports). Assisting with various tasks enabled the researcher to build rapport and gain invitations to significant conversations and journeys to remote clinics that would have been far less accessible to anyone perceived as an outsider. Additionally, as Walsham, Robey and Sahay (2007, p. 324) argue, researcher participation in projects of technology development and use is “particularly relevant in contexts where resources are scarce, when it can be argued that outside researchers should not only go away with data for their academic papers, but should also aim to make a contribution in the research setting itself”.

The bulk of fieldwork, including hundreds of informal conversations, involved the Medic Mobile and Nexleaf project managers with primary responsibility for TempTracker implementation (n = 3). Additional key informants included the Ministry of Health nurses who attended trainings and implemented TempTracker devices (n = 32), many of whom the first author interviewed more than once. We interviewed four managers employed by the Mavueni District Ministry of Health with responsibilities related to immunization or equipment maintenance as well as Medic Mobile’s regional director, regional designer, and CEO and Nexleaf’s CTO and CEO. After half a dozen initial in-depth formal interviews to orient to the case, the first author interspersed the remaining audio-recorded interviews (44 total) with clinic visits. Later interviews typically revolved around topics that arose during clinic visits and often involved photographs that the first author took following Harper’s (2002) description of photo elicitation. For example, taking pictures of partially completed paper reports (Figure A4) and showing them to nurses facilitated conversation about how much of the cold chain was invisible to managers. Photos of first- and second-generation devices (Figures A6 and A7) prompted reflection on the growing “kit” of ancillary user resources and how the new resources reflected awareness of the growing number of tasks that TempTracker users had to perform.

As most practitioners struggle to articulate the specifics of their work outside of the context of actually doing it (Barley & Kunda, 2001; Schön, 1983; Suchman, 2006), the first author often interspersed informal interviews with tasks such as preparing for a training or troubleshooting a device that was not functioning properly. The author wrote cursory notes of informal interviews (62 total) during or immediately after these conversations with descriptive and reflexive elaboration recorded within 24 hours. Additional field notes documented events (e.g., a distinctive malfunction observed at a particular clinic) and practices (e.g., switching out components such as batteries or sensors to isolate a malfunctioning element). The ethnographer’s privileged access also resulted in being copied in on 658 emails that contained 74 key project documents, including work plans and presentations for the Ministry of Health that we quote in the findings below.

<table>
<thead>
<tr>
<th>Field notes: detailed written records of events (e.g., a clinic visit or a distinctive device malfunction at a particular clinic), practices (e.g., systematically switching out device components such as batteries, SIM cards or sensors to isolate a malfunctioning element) and mundane activities. Supplemented by extensive notes on the ethnographer’s reflections and feelings throughout 88 days of fieldwork.</th>
<th>Coded to trace emergent themes and referenced while writing thick descriptions of notable events and practices.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photographs and videos: over 3,200 photographs and videos documenting events that often unfolded too quickly to take notes in real time. Notable photos were captioned and discussed in field notes before retiring each evening.</td>
<td>Used to capture key phenomena in rich detail, which helped the ethnographer write thick descriptions and convey a sense of the field to the second author and readers (see Appendix). Ethnographer also showed photographs to informants to evoke responses during interviews.</td>
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Table 1. Data Sources and Uses
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<th>Data Source</th>
<th>Description</th>
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<tr>
<td>Informal interviews: with nurses and all TempTracker team members in Kenya (62 interviews in total) to discuss observations and issues that emerged in participant observation or interviews with other informants. Informal interviews were occasionally unplanned as compelling conversations emerged out of ordinary socializing. Ethnographer recorded cursory notes during or immediately after interview, with more detailed elaboration within 24 hours.</td>
<td>Integrating observations with informants’ accounts, seeking to confirm or disconfirm emergent insights through constant comparison, coded to trace emergent themes and referenced while writing thick descriptions of notable events and practices.</td>
</tr>
<tr>
<td>Formal interviews: audio-recorded interviews with individuals or small groups of nurses, managers and TempTracker team members.</td>
<td>In-depth interviews helped orient the ethnographer to the case and establish the project’s timeline. Later interviews revolved around integrating observations with informant accounts; for example, interviewing the Ministry of Health director of maintenance for context on the feasibility/difficulty of the new tech support role that the TempTracker team hoped to establish.</td>
</tr>
<tr>
<td>Project-related documents: 658 emails discussing project updates and work plans, spreadsheets with logs of clinic visits and TempTracker malfunctions, training support material, proposals, presentations for Ministry of Health, project funders.</td>
<td>Triangulating with copied-in emails and attached reports/presentations was vital for discovering how the “official line” that distinguished human error from device breakage differed from the ethnographer’s observations “behind the scenes” about their entanglement (e.g., talk during team meetings of the devices’ becoming “expensive blocks of plastic” without tech support).</td>
</tr>
<tr>
<td>Field notes: detailed written records of events (e.g. a clinic visit, or a distinctive device malfunction at a particular clinic), practices (e.g. systematically switching out device components such as batteries, SIM cards or sensors to isolate a malfunctioning element), and mundane activities. Supplemented by extensive notes on the ethnographer’s reflections and feelings throughout 88 days of fieldwork.</td>
<td>Coded to trace emergent themes and referenced while writing thick descriptions of notable events and practices.</td>
</tr>
</tbody>
</table>

4.5 Data Analysis

To analyze the data, we began by documenting instances of back talk (Schön, 1983; Yanow & Tsoukas, 2009). We paid particular attention to difficulties in Kenya that related to the materiality of the prototype and that had not been observed during lab testing in California. During the first author’s first six-week stint of fieldwork, he immediately recognized that some instances of back talk were attributed not exclusively to the TempTracker device itself or to user perceptions and actions but to differences in material infrastructure between California and Kenya. In the initial open coding that followed this round of fieldwork, we also noticed codes related to “back talk” co-located with codes related to new forms of “visibility”, “monitoring”, and related concerns of “accountability”. For example, multiple nurses reported that their device was sending faulty SMS alerts and explained that it concerned them because their managers might receive the faulty alerts and perceive them to be lazy or underperforming workers.

In comparing our codes to existing research, we began to consider these tensions related to accountability and supervisor scrutiny as a process of emergence and to reflect on whether or in what sense design work might shape emergent practices. Particular roles, routines, and new coordinating practices (e.g. phone calls to “shout for help” in cases of fridge failure) then became more explicit topics of observation, interviews, and coding during the second and third rounds of fieldwork. As in other cases of longitudinal ICT4D research, by spacing stints of fieldwork across a period of several years, we could develop a more holistic picture of how the initiative unfolded (Latifov & Sahay, 2013; Luís Mosse & Byrne, 2005).

During the third round of fieldwork, the TempTracker program had been implemented in all of the health facilities in an entire district, and the design team was increasingly concerned with documenting bugs and non-functional devices so as to inform long-term maintenance. In an attempt to reconcile all of our codes that pertained to distinct kinds of malfunction (e.g., #databacklogerror), we realized that some instances had surfaced repeatedly with ambiguous origins or were diagnosed inaccuracy before anyone identified the actual cause. Eventually, this insight led to our interest in practice breakdowns and the idea that experiences of breakdown may precede awareness of material back talk as the source of a malfunction or difficulty. The second author, who did not take part in fieldwork, acted as an “outsider” in dissecting and
challenging emerging codes for these data (Evered & Louis, 1981). As Walsham (2006) observes, advantages of the “insider” or involved perspective of ethnographers and action researchers include excellent access to people, issues, and data. However, involved researchers may become socialized to the views of people in the field and lose critical distance. By bridging an ethographic fieldworker’s (first author) experiential involvement and intent to understand the situation from a practitioner’s point of view with a more detached researcher (second author) who interpreted data in light of established analytic categories, we hoped to uncover empirically grounded yet generalizable knowledge.

To lift our initial case analysis to a more conceptual level, we used Langley’s (1999) widely cited guidance for theorizing process-oriented data through narrative analysis and visual mapping strategies. To do so, we first drew on all of the data sources that we describe above to write “thick descriptions” (Geertz, 1973) of episodes in which back talk seemed consequential for the emergence of new practices. In these descriptions, we aimed to convey the richness and detail of our data. For the sake of brevity, we selected just three vignettes to discuss in this paper. Our informants regarded all three episodes as highly consequential for the overall success of the TempTracker initiative, and each episode clearly illustrates the significance of materiality, human agency and emergence in the unfolding design process. That is to say, these vignettes present the breadth and depth of relevant data and speak to the point and purpose of ethnography: “to render the actual—and to do so persuasively” (Van Maanen, 2010). Several practice-based studies in IS and organization have adopted similar narrative approaches (Mazmanian, 2013; Oborn, Barrett & Davidson, 2011; Smets, Jarzabkowski, Burke, & Spee, 2015).

We then constructed graphical representations of these episodes to serve as “an intermediary step between the raw data and a more abstract conceptualization” (Langley, 1999, p. 702). By comparing graphical representations of each of our narratives, we could better identify commonalities in how these episodes unfolded and patterns of difference. Through this exercise, we produced the three rows (one for each episode) and six columns of data that we organize in Table 2. After extended reflection, we began to consider the activities that reoccurred in each narrative in more general terms as conceptual building blocks that we could use to understand other cases of designing for the emergence of sociomaterial practices. This highly iterative process entailed cyclically reading and rereading our data and the literature, reflecting on our emerging theoretical arguments, and responding to the perspectives of a highly engaged editorial team.

As Langley (1999, p. 691) astutely observes, “no analysis strategy will produce theory without an uncodifiable creative leap, however small”. For ethnography in particular, researchers have long recognized that moving from thick descriptions to perception of more general patterns and, ultimately, to an account that is more analytical and integrated with current research is often less structured than one might expect of interview-based approaches to qualitative research (Pratt, 2000; Van Maanen, 1979). This approach has the obvious limitation that it results in analyses that are inherently exploratory rather than the one inevitable or authoritative interpretation of a particular case. In this spirit, the following narratives offer a close-up and in-the-thick-of-action exploration of the imbrication process in an ICT4D initiative.

5 Findings

5.1 Local Infrastructure and Material Back Talk in the Process of Imbrication

In October to December, 2012, implementing staff at Medic Mobile and Nexleaf delivered the devices to each of the eight clinics that participated in the initial pilot and briefly discussed the purpose of the device and SMS messages with the nurses in charge at these facilities. They then configured the devices to send SMS messages to the facility-owned phone that the nurse in charge normally held. The TempTracker software application could send temperature alerts via SMS text messages to any phone once that phone number was registered or subscribed in the TempTracker app. In most facilities, just one or two nurses were subscribed to receive updates. The software would send routine temperature readings at 8 a.m. and 4 p.m. daily, and an SMS alert would be sent anytime, day or night, if the fridge was outside of the 2-8°C range for over ten minutes.

The TempTracker Web dashboard indicated that, soon after the installation of eight TempTracker devices for the initial pilot, the devices began uploading temperature data as expected. However, nurses’ comments concerning the accuracy of SMS notifications varied from clinic to clinic. When asked whether the SMS were accurate and how they knew, some stated unequivocally that the device sent accurate, helpful temperature information to their phones. Many nurses mentioned that they had verified the temperature readings in the routine SMS notifications by visually inspecting traditional thermometers. This
practice seems to have been particularly common at smaller facilities, where the nurse in charge who held the facility phone would often manually chart the fridge temperatures personally (rather than delegating to another worker). In other cases, nurses told stories of responding to emergency alerts and finding that their fridge was indeed outside of the acceptable temperature range:

**Nurse:** There was one time the power was out at midnight Sunday, and we didn't have any clients [arrive in need of emergency care] all night. And normally it's a Sunday morning and you want to sleep and you think the lights are on. But we received this message and you wake up very active, very fast indeed.

**Researcher:** And it was right, the message was right?

**Nurse:** Yes! The power was out and we switched over to propane.

A more dramatic learning event occurred several weeks into the pilot at a time when nurses in the region were on strike and demanding what would be their first salary increase in several years. The power went out at the facility and, although the nurses were not there to notice it, the nurse in charge had taken the facility phone home with her and received an alert. Torn between breaking the strike and letting an entire fridge spoil, she called someone in the district capital to request that they come switch the fridge to propane back up. Some of the vials did spoil on this occasion, but the event underscored the utility of the TempTracker device and staff at this facility became enthusiastic supporters of the program.

In contrast, other facilities reported ongoing problems with the device:

**Nurse:** Okay, in my facility it used to give us alerts but when you just check, like at six A.M. DEET DEET [a beeping noise mimicking the tone of a phone receiving a message], “temperature dangerously low”. You check, you find it okay. Again at eight DEET DEET, “temperature dangerously low”. You check, you find it okay.

**Researcher:** So it was faulty?

**Nurse:** Yeah maybe there would be something faulty. In our case it was “dangerously low, dangerously low” and our thermometers were not off.

After the interview, the researcher walked around the facility and saw that the temperature sensor was sitting in a puddle of water at the bottom of the fridge and also that the sensor was wrapped in a two-centimeter cube of foam. When the researcher pointed out to the Medic Mobile implementer who was present, he pulled off the foam to squeeze the water out, and then explained to the nurse, not for the first time he would later remark, that the sensor needed to be placed in a tray just like the other thermometers. He later mentioned that the engineer from Nexleaf (who had left Kenya before the first round of fieldwork for this study) had added the foam cubes to all eight devices a few weeks into the pilot in an effort to address initial complaints of inaccurately low temperature readings. The hypothesis was that the sensor may have been brushing up against a piece of ice or cold metal, but adding foam cubes did not seem to solve the problem.

Back at a lab in the United States, the Nexleaf engineers dug deeper into the temperature data via the online dashboard. They eventually noticed occasional changes of 2-6° far faster than the actual temperature could be changing. Such fluctuations did not occur with devices in the lab, so they reasoned that the errors must have something to do with the local context in Kenya. One of them eventually hypothesized that the fluctuation in temperatures was due to electrical “noise”—a stray electrical signal that the phone’s audio jack picked up. The temperature sensor was designed to convert a temperature reading to an electrical signal that could be sent to the phone by plugging the temperature sensor into the phone’s audio jack. The hypothesis was that the headphone jack was picking up electrical signal from unexpected sources in addition to the sensor, so that the signal received by the audio jack was different than that being sent by the temperature sensor alone. According to a Nexleaf engineer, that amount of electrical noise is atypical in North America, but the lab eventually reproduced some of the temperature reading noise by surrounding a TempTracker device with halogen lights and a wall heater. Having identified noisy electrical signal as the culprit, the engineers then developed a software algorithm to filter the temperature readings. Thinking that temperature data would be the only electrical signal that would feed into the phone’s audio jack, they had initially programmed TempTracker to capture signal amplitude at any frequency. However, they knew that the frequency of the temperature signal was 435 Hertz, and, by switching from sampling all frequencies at given points in time to sampling only at the specific frequency of 435 Hertz, they could filter out the noise at different frequencies (see Figure A9). As a result, the temperature readings became more precise once the lab implemented this filtering algorithm.
In this case, TempTracker’s performance in Kenya fell short of its performance in California because of how it related to local infrastructure. TempTracker engineers had not anticipated these particular infrastructure difficulties. However, the engineers’ decision to deploy the early prototype locally was predicated on the view that doing so would lead to insights that would not or could not have emerged in a laboratory. By enacting forms of back talk that would never have arisen during testing in California and by making the prototype devices more robust in response, the design team validated their decision to deploy the prototype locally and iterate rapidly. Thus, rather than regarding this episode as a temporary failure of TempTracker prototypes, one might understand it as an early success in designing through local conversations with materials. This case is just one of more than half a dozen in which the design and engineering team modified the TempTracker devices before the end of the initial pilot at eight facilities. While some of these iterations seemed relatively minor, implementers and health workers clearly deemed them serious enough that they would not expand the small eight-clinic pilot to more facilities until they were addressed.

5.2 Biological Materials, Back Talk in the Emergence of New Features and New Routines

In other cases, TempTracker was redesigned to accommodate local cold chain coordination routines. Nexleaf engineers initially had imagined that clinic-based nurses would act on real-time text message alerts and that automated data collection would come to replace district-level managers’ use of paper-based monthly temperature charts. However, our first round of fieldwork revealed that managers generally relied more on phone calls from nurses than on monthly reports for monitoring cold chain performance:

They [clinic-based nurses] are supposed to submit to us the cold chain recording sheet. If at a particular time the temperatures went up, they went high beyond the required limits, we normally call them to ask what happened and you never reported? (Supervisor)

The potential for an accusation that the facility “never reported” is telling given that the supervisor was describing how she would respond if she discovered a temperature spike while scrutinizing the most relevant paper-based report. While this managerial expectation initially surprised the technology designers, managers explained that they expected to hear about such important events long before receiving monthly reports in part because vaccines degrade rapidly. News of a cold chain malfunction hurled workers into a trouble-shooting pipeline in which they had perhaps a dozen hours or less to fix equipment or relocate vaccines. The temporal urgency of vaccine degradation underlay a mutual understanding among nurses and their managers that, while monthly reports are a bureaucratic necessity, timely “shouts for help” were vital for coordinating responses to cold chain disruptions.

Most nurses expressed appreciation for SMS temperature alerts for enabling them to coordinate responses to cold chain disruptions even when they were away from the clinic. As one nurse enthusiastically explained, “when I got this [TempTracker device], then I don’t have to go there [to the clinic] over the weekend because I just got the SMSs through my phone. Amen.” The alerts spurred responses to cold chain disruption much as a phone call “shout for help” from another worker would have. After discussing these alerts with nurses and implementers, managers also expressed interest in receiving real-time alerts rather than focusing solely on monthly reports. A negotiation then unfolded among managers who wanted real-time information and nurses who wanted time to act before facing the scrutiny of their supervisors.

Eventually, all parties agreed to a new feature: sending “escalated alerts” to managers five hours after nurses received word of a high temperature or half an hour after they received a cold alarm. These time buffers reflect a delicate compromise with consideration for the duration and improvisational nature of coordinated responses to cold chain disruptions, the relational priorities of managers and nurses, and their interpretations of biomedical knowledge concerning immunization. In this sense, cold chain coordination activities mediated the link between population immunity and the biological process of vaccine degradation, which is important because it again draws our attention beyond the prototype itself to the ways that TempTracker relates to the diverse material and human actors of particular situations.

5.3 Categorizing Breakdowns, Guiding the Emergence of a New Role

In less than two years, the initial eight-facility pilot expanded to district-wide use at more than forty clinics. While coordinated responses to cold chain disruptions typically reflected the temporal pace of vaccine degradation, another timeline had begun to pressure Nexleaf, Medic Mobile, and the Ministry of Health to consider the sustainability of their inter-organizational partnership. Like many global health initiatives, a specific grant funded the TempTracker program, and this grant was governed by a time-delimited
memorandum of understanding that representatives of all three organizations had signed. While Nexleaf and Medic Mobile initially provided the bulk of support and follow up to ensure the devices functioned, in the final months of the initial memorandum, there was growing concern that the ministry be fully prepared to provide on-site maintenance and support in the long term.

This capacity-building effort entailed identifying which ministry staff person(s) across various departments (local nurses; immunization, monitoring and evaluation, and maintenance staff at the district office; and Nexleaf engineers in California) had appropriate skills and availability for particular TempTracker maintenance tasks. It subsequently involved training these people and creating new role-specific guides and reference materials. Negotiating with higher-level managers to ensure that they officially approved these arrangements and allocated budget appropriately was necessary as well. Medic Mobile and Nexleaf were now trying to place the logistical needs of the project at hand in broader health system context and to approach these negotiations with the understanding that all Ministry of Health staff had many other priorities and international aid projects to contend with.

While there was a clear sense that only the ministry could sustain local support tasks in the long term, Nexleaf would also clearly need to play some role in troubleshooting, repairing, or replacing devices with more complex or atypical problems. At this stage in the design process, categorizing ordinary disruptions (to be dealt with locally) and “beyond ordinary” malfunctions was a non-trivial challenge. Moreover, Nexleaf and Medic Mobile staff also realized that they needed to help construct a reasonable value proposition for the cash-strapped ministry to take accountability for these tasks or else accept that the project would falter. As one implementer remarked during a teleconference, without tech support capacity at the ministry, TempTracker devices would “shut down one by one on their own. At that point we have to acknowledge that the program won't be sustained and we're actually funding heavy blocks of plastic.”

As these inter-departmental and inter-organizational coordinating activities proceeded, Nexleaf and Medic Mobile staff continued implementation and design activities—a priority in part because determining which people had appropriate skills to account for particular tasks entailed reassessing how robustly the devices were performing at that point in time. A number of known problems had been addressed and many devices were uploading data and sending alerts daily, yet others were not functioning, and, from the district office (let alone abroad), it was often unclear why. Upon visiting clinics where TempTracker was not functioning, the first author found that, in some cases, devices had simply been left unplugged or nurses had not added airtime as planned, but other cases reflected a more complex process of disruption. Eventually, it became clear that devices at a handful of clinics had taken temperature readings every ten minutes for weeks or months but had not uploaded any data. At most of these clinics, financially constrained nurses had for some time not replenished airtime for connecting to the mobile phone network. In at least two clinics, mobile Internet connectivity had simply been atypically poor for several months. Eventually, the devices accumulated larger amounts of temperature data than the lab had ever tested, which caused the TempTracker software to freeze, which meant the devices could not upload data even after airtime had been replenished.

Early in the project, designers, implementers, and engineers at Nexleaf and Medic Mobile typically saw such disruptions as calls to redesign the device or user workflows. However, efforts to establish accountability and role clarity had generated growing attention to categories of “user error” and “device breakage”, which local staff or engineers in California, respectively, would account for. For malfunctions with a substantially ambiguous or mixed origin, the design team felt growing pressure to blame human error rather than interpreting these malfunctions as instances of material back talk. While local staff presumably could have addressed the former more sustainably, the latter kind of malfunction would have necessitated further redesign of routines or devices, which was becoming organizationally problematic.

The pressure to categorize accountability was so great that a presentation for the ministry of health, sent in an email with the researcher copied in, summarized these problems as follows:

*The most common problems were due to user-errors.... The current problems are not in the technology but in the deployment plan, the roles and responsibilities of all the parties involved, and the procedures around maintenance and support. These should all be strengthened to complement the current infrastructure of the Ministry of Health.*

This statement contains a certain factual accuracy: the problems were not exclusively in the devices so much as distributed throughout the situated practice as a whole. For the design team, this seemed patently obvious because these particular breakdowns had never materialized during extensive testing, admittedly under ideal conditions, in California. This episode shows that, while material back talk has some objective
reality apart from any person’s believing in it yet, it is also enacted in practice rather than being a fixed feature of any one object. As a result, considerations about which aspects of a practice might be reconfigured to accommodate material back talk hinge on subjective judgment and organizational pressures.

This one-sided formal conclusion marked a shift in the design process. The design team’s scope of work had expanded beyond technology design with a view to establishing new roles and routines for the sake of achieving a more coordinated, effective vaccine cold chain. However, this shift was not away from technology design. Despite their formal decision to draw attention to user error, the design team remained aware that, in the ambiguous case above, poor connectivity and not replenishing airtime had led to cases of device breakage in ways that were irreversible and opaque to ordinary users. For pragmatic reasons, they continued working to clarify the nature of the bug and to address it through changes to the software codebase.

In summary, later in the project, the design team faced growing pressure to categorize breakdowns and, despite the indeterminacy of causes and effects, to delineate which parties would be accountable for addressing them in the future. When we consider how the design team spoke about their ongoing work, particularly in formal presentations, they tended to make clear distinctions between organizational intervention and technology design. Yet, in their practice of recognizing and responding to instances of material back talk, they demonstrated an acute sense for the performance of their intervention as a whole. Responding to material back talk by redesigning the maintenance role suggests that they were attending to the evolving relations among technology and situated work as much as they were attending to the inherent features of either considered as separate entities. After extended reflection, we came to describe their design process as a matter of guiding the emergence of sociomaterial practices. In Section 5.4, we consider several themes that span these three narrative episodes and offer our inductive insights about how this process happens.

5.4 Case Analysis

Each of the narratives above illustrates how the imbrication of human aims and material back talk shapes the emergence of new practices. We can also identify certain important recurring elements in each of these rounds of imbrication. Considering these recurring activities in more abstract terms, we identify key conceptual building blocks that one could use understand similar processes of imbrication in other contexts. These activities include: 1) implementation and situated use of prototypes, 2) experiencing practice breakdown, 3) identifying material back talk as a source of practice breakdown, 4) accommodating material back talk, 5) reconfiguring material artifacts or/and worker routines, and 6) the ongoing performance of new practices.

In our case, this cycle of imbrication occurred repeatedly: prior imbrications laid the groundwork for subsequent imbrications in what Leonardi (2011) calls a chain of imbrications. This process has a temporal flow, yet one should regard the activities as mutually constitutive rather than self-contained or sequential. And while designers played a consequential role, they clearly did not predict or control the course of these narratives. To underscore this point, we refer to the proactive kind of imbrication that we observed as designing for the emergence of sociomaterial practices, in contrast with a notion of simply designing sociomaterial practices, which might ascribe more control or prescience to designers.

In Table 3, we synthesize key observations from Sections 5.1 to 5.3 and organize them to show that each episode is an illustrative case of this general process. Each column of the table draws observations from a single episode, while each row features observations from all three episodes that pertain to a single conceptual building block. We explain these conceptual building blocks in further detail next.

5.4.1 Implementation and Situated Use of Prototypes

We begin each of the narrative episodes above with implementation and situated use of prototype technologies in a particular local context. In contrast with other recent studies that have explored the concept development stage of design work that precedes functional prototyping (Stigliani & Ravasi, 2012), we use the metaphor of imbrication to focus on the kind of contextually embedded, ongoing design-in-use that can only take place once technology has enabled provisional new ways of working. This emphasis is important because it is through enacting new ways of using technology that health workers simultaneously enacted surprising forms of back talk. These included faulty temperature alerts (episode one) and data backlog errors (episode three) that had not been enacted outside of the context of actual use (during laboratory testing).
Table 2. Designing for the Emergence of Sociomaterial Practices

<table>
<thead>
<tr>
<th>Activities recurring in all episodes</th>
<th>Data from narrative 1</th>
<th>Data from narrative 2</th>
<th>Data from narrative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implementations and use of prototypes</strong> (beginning imbrication, enacting back talk)</td>
<td>TempTracker prototypes were installed and began sending temperature alerts. Nurses responded or/and mobilized others to respond to cold chain disruptions.</td>
<td>Nurses now received real-time SMS alerts but were not always available to see or respond to them. Also, monthly reports were designed for managers but, in practice, they preferred real-time alerts.</td>
<td>Nurses and managers began coordinating responses to cold chain disruptions via real-time and escalated alerts. Doing so required nurses to add mobile network airtime and tech support from Nexlia/Medic Mobile.</td>
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<tr>
<td><strong>Practice breakdown</strong> (adverse experiences in unanticipated situations)</td>
<td>Nurses reported that some alerts were inaccurate and online dashboard showed that temperature readings occasionally spiked more sharply than seems attributable to actual temperature variations.</td>
<td>Managers at Ministry of Health were enlisted in responses to cold chain disruptions through timely phone calls or by subscribing to SMS alerts, but the latter raised scrutiny/accountability concerns among nurses.</td>
<td>Clinic visits revealed a pattern of “frozen” software at clinics where devices were accumulating temperature data for weeks without uploading it to Internet.</td>
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<tr>
<td><strong>Investigating breakdown</strong> (sources included material back talk)</td>
<td>Placing foam blocks on temperature sensors to buffer them from cold surfaces did not address inaccuracies. Cause was ambiguous until engineers speculatively reproduced electrical noise in lab.</td>
<td>Proposed to delay SMS alerts to managers by 24 hours, which revealed that managers were concerned with a material limit: vaccines degrade rapidly, imposing a strict timeline on responses to cold chain disruptions.</td>
<td>Upon deleting data backlog and rebooting devices, they functioned as normal, which confirmed that data backlog was contributing to the software freeze.</td>
</tr>
<tr>
<td><strong>Accommodating material back talk</strong> (Exploring preferable tech and routines)</td>
<td>Confirmed hypothesis that headphone jack design was picking up stray electrical noise in Kenya that had not been present in California and that readings could be filtered with a new algorithm.</td>
<td>Nurse accountability concerns about being monitored in real time were balanced with the material constraints of vaccine degradation, which resulted in the design of an “escalated alerts” feature.</td>
<td>Initially emphasized changes to user behavior (be sure to replenish devices with mobile network airtime) rather than technology redesign.</td>
</tr>
<tr>
<td><strong>Reconfiguring artifacts, routines</strong> (tech and routines emerge, guided by design goals)</td>
<td>Designed and built software algorithm to filter effects of electrical noise out of temperature readings.</td>
<td>Built escalated-alerts feature and configured it to alert managers 30 minutes (fridge too cold) or five hours (fridge too hot) after alerting nurses.</td>
<td>Attributing the episode to the “human error” shifted focus from reconfiguring technology to retraining in order to establish more consistent patterns of action</td>
</tr>
<tr>
<td><strong>Performance of new practices</strong> (shaped by imbrication of material and human actions)</td>
<td>Deployed updated software for more reliable alerts; trained additional health workers on new routines for coordinating responses to cold chain disruptions.</td>
<td>Deployed updated software; managers began receiving escalated alerts and calling nurses to initiate responses to sustained cold chain disruptions.</td>
<td>The local TempTracker support role that emerged had as much to do with retraining and promoting key work routines among nurses as it did with technical maintenance of TempTracker devices.</td>
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While the design practitioners with whom we worked did not use the terms material back talk or emergence themselves, they clearly implicitly recognized these phenomena in their work. TempTracker devices were nominally functional during the eight-facility pilot recounted in episode one above, yet nurses and TempTracker implementers discussed at length that both the technology and the new ways of working that it might enable were liable to change. The design team members organized this initial situated use of technology in the hope that it would enable them to discover what changes they should make as the situation unfolded. In light of the highly exploratory character of this activity, for practical purposes, it began with a relatively small number of devices/users, and the design team discussed it as “piloting”: the team often spoke of taking TempTracker “from the lab to the field” in order to “see how the technology breaks”. From the perspective of the design team, the nurses’ initial technology-enabled work was highly provisional; its purpose was to generate grounded insights and unanticipated turns in the emergent design process. The design team retained this emphasis on pursuing iteration and course
correction without foreordaining the form or path that it would take through episode two. However, as we discuss below, it began to recede as the formal design work came to a close in episode three.

5.4.2 Experiencing Practice Breakdown

The second activity, experiencing practice breakdown, comprised registering patterns of puzzling or unappreciated consequences related to use of prototypes. In our case, the design team actively sought to discover and document worker experiences of practice breakdown (e.g., through conducting interviews and focus groups, visiting remote clinics for hands-on troubleshooting, scrutinizing the online dashboard, and making phone calls to clinics whose devices were not uploading data). Despite this proactive attention, breakdown often emerged ambiguously rather than presenting itself in the form of a problem ready for solution. For example, designers and the researcher all repeatedly heard or observed nurse reports of faulty temperature readings (episode one), their intuitive skepticism about accountability issues (episode two) and software freezing due to data overload (episode three) in some sense before we registered them as recurring patterns of significant disruption. Drawing on phenomenological treatments of practice breakdown is helpful here because prior work in this vein has drawn attention to how varying degrees of disruption can engender varying degrees of surprise, unreflective workarounds, or more conceptual attention to sources of breakdown. While anyone may easily recognize an obvious and/or total disruption in a practice, designers are often in a position to allow themselves to notice and investigate more minor instances of practice breakdown, or not, in accordance with their goals, skills, and habitual ways of working.

5.4.3 Investigating Sources of Practice Breakdown

In each of the episodes above, awareness of practice breakdown began with a relatively undifferentiated flow of reports from nurses about “broken gadgets” complemented by observations about which devices were not uploading data to the server. Differentiating this flow into lists of recognizable kinds of recurring problems involved a kind of design-oriented investigative work. For example, awareness that software froze on multiple devices preceded awareness that it occurred specifically on the subset of devices that had remained functioning continuously but without connectivity (episode three). On more than one occasion, designers and engineers investigated forms of back talk through efforts to recreate them. For example, engineers created electrical noise in the lab in California and observed that doing so generated faulty temperature readings of a recognizable pattern, which it took as evidence that similar faulty readings in Kenya had indeed resulted from electrical noise (episode one). In general, this work was probing and analytical and directed toward convergence or agreement regarding the attributes that characterize a particular form of breakdown.

It bears mentioning that we purposively selected episodes of practice breakdown that we researchers ultimately attributed, at least in part, to material back talk. However, material back talk was not the only meaningful source of practice breakdown; more simply, it was an important source. Further, while episodes two and three involved unforeseen imbrications of device materiality and local routines that existed before the TempTracker initiative, all three episodes involved the device’s interacting at some level with local infrastructure. Designers had to deal with the materiality of the local electrical grid in episode one, the materiality of vaccines and the pace of biological degradation in episode two, and the nominal Internet connectivity at some health clinics in episode three. For this reason, the notion of material back talk affords a wider field of vision than the notion of constraints, at least insofar as perceptions of constraint are limited to the materiality of IT artifacts. In analyzing material back talk, we found a clear theme dealing with the imbrication of multiple kinds of materials in complex practice, which we discuss further below.

5.4.4 Exploring Ways of Accommodating Material Back Talk

On several occasions, moves to clarify the nature of some particular kind of practice breakdown proceeded through provisional attempts to accommodate it. For example, recall the Nexleaf engineer who placed foam blocks on the tips of temperature sensors. This action constitutes a kind of improvised “hack.” If it had been followed by a change in the pattern of faulty temperature readings, the designers would have seen the change as affirming that the faulty readings of episode one resulted from the sensor’s coming into contact with ice inside the fridge. In other cases, talking with technology users about proposed responses to breakdown enabled the designers to gather insights based on the users’ familiarity with important routines and concrete material constraints. For example, in the case of the escalated-alerts feature (episode two), the design team perceived an initial practice breakdown in nurse-supervisor accountability relations as a
consequence of managers’ receiving real-time alerts. Only after the team proposed to address this practice breakdown with an SMS alert delayed by 24 hours did users explain to the design team that they would face material back talk related to the rigid temporal pace of vaccine degradation.

The importance of on-the-spot experimenting and clarifying problems through provisional attempts to address them underscores how this probing form of design-oriented inquiry differs from more passive modes of observation and interpretation. One result of this way of working is that the temporal ordering of two conceptually distinct activities, investigating practice break down and experimentally accommodating material back talk, may be quite ambiguous. They may even proceed through the very same actions, but it remains worthwhile to understand their ends as conceptually distinct. Investigating breakdown is analytical and seeks convergence around an idea of where and how a particular kind of disruption emerged; in contrast, exploring reconfigurations is generative, and provisional solutions reflect the emergent character of the back talk they address. While we could depict designers as the sole agents who drove the generative part of this process, we instead call this work a kind of accommodation to emphasize that the problems, puzzles, and difficulties they addressed emerged in the recurring performance of devices and users in particular contexts. Thus, in some sense, users and the materials of the situation set the terms of imbrication and produced particular kinds of emergent complexities before designers could address them through further iteration.

5.4.5 Reconfiguring Artifacts and Routines

A fifth activity entailed rebuilding prototypes to accommodate concrete experiences of material back talk to guide the emergence of new practices. For example the escalated-alerts feature (episode two) materialized and eventually became integral to new routines for coordinating responses to cold chain disruptions—new in the sense that the development team had not anticipated this particular managerial routine when initially building the device. Interestingly, after identifying nurses’ concern with scrutiny as a priority and the pace of vaccine degradation as a hard limit, the development team made changes in the software to configure the timing and scheduling of alerts and in the ostensive patterns of action that these alerts supported. Similarly, when the development team attributed faulty temperature readings to the electrical grid, it designed a software algorithm to address the problem rather than trying to change the source of electricity. And our third episode shows how attributing a particular instance of back talk to human error can influence the kinds of material and activity reconfigurations that one does or does not explore. In this way, there is a fuzzy link between sources of and solutions to material back talk. The complexities designers must confront have an emergent character, and yet technology designers do guide the course of this emergence process insofar as they determine how to address each instance of material back talk.

Creating ancillary resources such as training manuals and troubleshooting guides also characterizes the work we call reconfiguring materials. In our case, the design team members knew that they could not establish new patterns of action by decree, yet their effort to build artifacts such as training materials was clearly predicated on the intention of changing health workers’ patterns of action in concrete ways. In episode one, the design team accommodated material back talk by building an algorithm while more or less validating the routine manner in which it had previously imagined that nurses would use the technology. In contrast, the team designed the escalated-alerts feature to enable the future performance of manager routines that would be new to this workplace and that the designers had not anticipated in earlier iterations of their work. This move in the design process also involved dropping some major features and attendant routines that had figured prominently in earlier specifications (in particular, the aggregate data-visualization tools and monthly monitoring activities that designers initially had expected managers to perform). In episode three, discussion of a data backlog error played a prominent role in determining the necessary skillset and writing the job description for local maintenance staff, a role which designers had only imagined in foggy form prior to concrete encounters with actual routine problems.

5.4.6 The Ongoing Performance of New Practices

In some cases, the implementation of reconfigured technologies and the ongoing performance of a new practice generated new experiences of practice breakdown. For example, the development team addressed faulty temperature alerts during the eight-facility pilot in episode one by building a new algorithm, which became integral to the updated devices later implemented at more than forty facilities. Only with this larger round of implementation and increasing confidence in the accuracy of the SMS alerts did a more noticeable number of nurses begin voicing concerns about real-time scrutiny—the practice breakdown we recount in episode two. In this way, we can picture building artifacts and implementing artifacts and evaluating breakdowns as a continuous and ongoing process—what Leonardi (2011) calls a chain of imbrications. In
such situations, the ongoing performance of new practices may bear a great resemblance to the implementation and situated use of prototypes with which the process of imbrication began.

Some organizations perpetually redesign and improve major products (e.g., the Linux operating system and Wikipedia) without any intention of arriving at a complete and final version (Garud, Jain, & Tuertscher, 2008). However, many organizations will likely stop investing in design work at some point in a project. If the organization considers the intervention to be sufficiently robust or validated, implementation may proceed without such deliberate ongoing redesign, which may be particularly true of ICT4D projects that use donor funds and have inflexible timelines. In our case, this relative stabilization of practice began in episode three and was marked by discussing technology “products” rather than “prototypes” and formalizing long-term maintenance roles so that the design team could “hand over” troubleshooting tasks to local Ministry of Health staff.

We do not suggest that patterns of action subsequently become static and unchanging but rather that, when people begin perceiving technologies as less subject to change, they may become less likely to attribute a given practice breakdown to material back talk. Users may be asked to resign themselves to minor disruptions as “the way things are”, or breakdowns may be attributed to human error instead of being treated as generative opportunities for redesign. In some cases, glossing over an instance of material back talk may have little serious consequence; people are quite adept at improvising workarounds to accommodate the quirks of technologies that do not precisely fit their preferred uses. Yet, in other cases, unaddressed instances of material back talk could have serious consequences, such as the breakage, nominal use, or outright rejection of technology. The data backlog bug that we describe in episode three materialized in just enough devices that, had it not been explained or addressed in some manner, it might have caused Ministry of Health leadership to lose faith in and discontinue the whole project. We depict the ongoing performance of new practices as at least potentially distinct from the situated use of prototypes to recognize that the process of imbrication can only continue in the manner that we describe here as long as technologies are subject to ongoing changes.

6 Discussion

In summary, we offer two novel findings: 1) we identify six overlapping activities that characterize designing for the emergence of sociomaterial practices and 2) we elucidate how successive imbrications of material back talk and ongoing design work shape this process of emergence. We now discuss these findings in terms of the contributions they make to IS design research and the ICT4D literature.

6.1 Sociomaterial Practices in IS Design Research

For IS research generally, the novelty of our contribution lies in the particular manner that our analysis integrates the concepts of imbrication, practice breakdown and material back talk. In Leonard’s (2011) seminal work on how human and material agencies imbricate to produce sociomaterial practices, user perceptions of a technology’s affordances and constraints play a central role. He takes perceptions of a technology’s constraints as evidence of material agency, and he associates perceptions of the functions or capacities for action that a technology artifact affords with the agency that technology users exercise with respect to how they enact practices. In this sense, constraints and affordances are relational: they exist between people and an artifact’s materiality (Leonardi, 2011).

This relational perspective on affordances and constraints helps to explain how technology may shape practices and yet how those practices may still change across different contexts of technology use, even where a technology’s materiality does not change. However, our case highlights that the performance of devices depends not only on how users perceive a discrete technology artifact but also on material infrastructure. The great differences in infrastructure between Kenya and California, and the way these differences informed our insights about the process of imbrication, demonstrate the value of using ICT4D studies to inform IS research theories more generally. In the ICT4D context, we can clearly see that we can expand our understanding of material agency by considering not only users’ perceptions of an IT artifact’s constraints but also the manner in which material back talk often emerges at the imbrication of devices and infrastructure.

We can similarly expand our view of human agency beyond the goals and perceptions of technology users by clarifying how the agency of technology designers matters. In our case, designers engaged deeply in contexts of use and acutely recognized the concrete material limits to their agency. Nevertheless, they played a more consequential role in guiding the emergence of practices than has been
 accorded to designers in recent studies of imbrication. In investigating practice breakdowns and accommodating back talk, designers acted skillfully and in accordance with their own goals for the project.

With that said, we do not mean to suggest that users’ initial perceptions of affordance and constraint were inconsequential in the process of imbrication. Rather, we highlight that, when people move to enact a certain practice based on an implicit perception of a technology’s affordance, they may be surprised by experiences of practice breakdown that cause them to reflect on their initial perceptions. In our case and likely in many others, technology users look to designers for support with investigating such experiences. Together, they may attempt to “make true” a perception of affordance; that is to say users might enlist designers to reconfigure technology so as to better align with an initial perception (episode one). Alternatively, designers may interpret material back talk as a previously imperceptible constraint and accommodate it by changing role definitions (episode three) or technology features and routines (episode two). Through these skillful judgments about how to accommodate particular instances of material back talk, designers can play an important, agential role in guiding the emergence of sociomaterial practices. To be sure, designers cannot control the emergent complexities that so often arise when people begin using their prototypes, but they can respond to them when they arise in practice.

An important implication of this novel analysis is that, by foregrounding the perspectives and work of designers in the emergence of sociomaterial practices, we extend the notion of imbrication to be more amenable to forward-looking approaches to design research. Our findings are particularly relevant to context-aware frameworks such as action design research (Sein et al., 2011). Our analysis aligns well with and illuminates further ADR’s call for continuous iterative cycles of artifact building, organizational intervention, and evaluation. As we consider how to move from our inductive analysis to prescriptive guidance for future design efforts, ADR’s notion of guided emergence is highly salient. Guided emergence suggests that design researchers “should (a) consciously guide the design of the artifact, and at the same time, (b) allow the artifact to emerge via influences from the organizational participants” (Purao et al., 2017 p. 77). Embracing guided emergence involves going beyond the classical tool-view (Hevner, Ram, March, & Park, 2004) implicit in much IS design research. For this reason, ADR introduces the notion of ensemble artifact as follows (Sein et al., 2011, p. 38):

**By ensemble artifact, we specifically mean the material and organizational features that are socially recognized as bundles of hardware and/or software (Orlikowski & Iacono, 2001). This definition reflects a “technology as structure” view of the ensemble artifact, where structures of the organizational domain are inscribed into the artifact during its development and use (Orlikowski & Iacono, 2001).**

By embracing a “technology as structure” view and emphasizing the reciprocal shaping of artifacts and organizational contexts, ADR holds that the materiality of ensemble artifacts is recognizably distinct yet, in practice, inevitably intertwined with human action. When pushed to clarify their understanding of ensemble artifacts in subsequent work, the authors state, “we suggested that IS scholars’ domain of intervention should be the ensemble artifact, i.e. not only the hardware-software instantiation but also the work practices of organizational participants relevant to the context in which the IT-artifact is realized” (Purao, Henfridsson, Rossi, & Sein, 2013, p. 77). We see some analytical tension across these definitions. Earlier work emphasizes bundles of software or hardware that are inscribed by, yet ontologically separate from, the realm action. In contrast, later work emphasizes a broader domain of intervention, implying that the ontological form of an ensemble artifact extends into the practices of organizational participants.

Our work offers a step towards resolving this tension by theorizing the process of imbrication through which human activity and materiality become intertwined. As with prior work on imbrication (Leonardi, 2011), we can consider material artifacts as existing in the realm of structure and people’s activity as existing in the realm of action, yet shift the unit of analysis away from the properties or impacts of discrete entities and onto their process of interweaving. The notion of sociomaterial practices implies this shift in analytical focus. It suggests that designing for emergence should not only be open to the contributions of organizational members but also responsive to the complexities and concrete instances of material back talk that inevitably arise in practice. It offers a nuanced and more holistic framing of what emerges when artifacts and patterns of action imbricate through ongoing cycles of building, intervention, and evaluation.

### 6.2 Unpacking “Context” in Research on ICT for Development

As Walsham (2017) notes, the significance of context is a theme of early and lasting importance in the ICT4D community. Robey, Gupta, and Rodriguez-Diaz (1990) argue that social context and cultural barriers
to implementation present greater difficulties than technical issues, and Walsham, Symons, and Waema (1988) similarly argue that researchers should conceptualize IS as social systems in which computing technologies are but one dimension. Researchers have explored issues of local adaptation versus standardization (Walsham & Sahay, 2006), indigenous development of ICTs (Bhatnagar, 1990), and participatory design as a means of overcoming contextual challenges (Korpela, 1990; Braa & Sahay, 2012). While these studies have offered major contributions to our understanding of ICT4D initiatives, Nicolini (2012) and other practice theorists have observed that IS and organizational researchers often overuse context as a catchall term to a point where it loses analytical purchase. In this view, “context” does not satisfactorily explain why technology implementation evolves or goes awry. Rather, context is itself a phenomenon that we need to explain and conceptually unpack. If we maintain that context matters and yet acknowledge that “context matters” has become a truism in ICT4D, then we can see a clear need for better conceptual tools to clarify the specific ways in which concrete features of local context become consequential in particular cases.

Our notion of designing for the emergence of sociomaterial practices offers a fresh perspective on context in two ways that assist ICT4D research. First, it highlights that technologies imbricate not only with local “social” context such as cultural norms and ways of working but also with a range of local materials. While previous research has highlighted infrastructural constraints in ICT4D, we offer a novel analysis of the process through which technology, local materials, and human activities imbricate. We show that, when designers and researchers recognize instances of material back talk for their potentially generative role in ongoing design-in-use, they can result in productive reconfigurations of an IT artifact and enable designers to guide the emergence of new practices. Understanding this process conceptually will enable ICT4D researchers to write more precisely about the specific ways that context comes to matter in particular cases—through the imbrication of human aims, imported artifacts, and myriad features of local infrastructure.

Second, our analysis emphasizes that ICT4D practitioners proactively shape, even though they cannot unilaterally control, worker roles and routines. To some degree, these organized social dynamics exist before ICT4D interventions and form part of the local context that ICT4D practitioners must navigate. Yet, they also become integral to the interventions that ICT4D practitioners iteratively refine, document in user guides and training materials, and hope to reproduce in other settings. That is to say, practices are “entangled with their contexts, not only shaped by them but simultaneously enacting them” (Howard-Grenville, Rerup, Langley, & Tsoukas, 2015). Our approach in tracing concrete instances of practice breakdown and material back talk is a nuanced manner of clarifying which particular features of social context become integral to the ongoing performance of ICT4D interventions. By reframing ICT4D interventions as sociomaterial practices rather than as artifacts, we can more holistically consider the bundles of artifacts and routines that practitioners aim to reproduce when they scale their interventions to new contexts.

In this way, our analysis of designing for the emergence of sociomaterial practices could inform an ICT4D-oriented branch of the research agenda that Monteiro and Rolland (2012) proposed that concerns the trans-situated use of integrated information systems. Such research would address the IS literature’s blind spot concerning how people accommodate the situated and emergent character of sociomaterial practices yet nevertheless achieve significant degrees of similarity between sociomaterial practices that are dispersed across a wide range of contexts. Given the focus on “pilotitis” and frustration with the poor reproducibility of interventions in the ICT4D practitioner community, such a research agenda seems particularly timely.

6.3 Implications for Practice

ICT4D and global mHealth practitioners continue to struggle with putting design principles into practice (Waugaman, 2016) thanks in no small part to the myriad implementation complexities and coordination challenges that hinder global health and development initiatives generally. ICT4D practitioners who take practice break down, material back talk, and designing for emergence seriously may be able to sharpen their perceptual capacities and undertake design and implementation work with greater nuance.

For example, episode three highlights that deciding when to conclude iterative redesign activities can be fraught for a variety of organizational reasons—particularly when financial resources are scarce. Prematurely ending design activities can stymie the ongoing performance of a practice, even if one considers the technologies in question to be “functional” by virtue of their having previously functioned well in other contexts. Generic calls to “think like a designer” (Brown, 2008), “involve the user”, or “develop
projects in an incremental and iterative manner” do no doubt have merits, but they can be difficult to apply to the unique qualities of particular cases. In contrast, we can cultivate a more situation-specific view of a design project’s progress by acknowledging that technologies inevitably imbricate with new contexts of use and that this imbrication often engenders unique instances of material back talk and can manifest in practice breakdown. The practical consideration shifts from “did we engage users?” or “were there iterations?” to whether one has investigated and accommodated instances of material back talk and whether experiences of practice breakdown have substantially receded.

To suggest designing for the emergence of practices rather than simply to design sociomaterial practices emphasizes that designers grapple with a range of emergent complexities that often evade their foresight when gathering requirements and that remain beyond their control during implementation. Though designers cannot predict or control these complexities, they can adapt to them when they arise and, thereby, guide the emergence of new practices. By revealing that this generative process proceeds through concrete conversations with materials and encounters with material back talk, our analysis casts a critical light on efforts to apply design principles while telecommuting or through brief sojourns in developing countries. Insofar as good design involves experiencing practice breakdown and investigating and accommodating unique instances of material back talk, it is hardly compatible with “parachuting in”—the term many international development practitioners use to describe transient visits by foreign aid workers. In this way, our study offers a concrete material basis for undertaking ICT4D design work locally and with the sustained participation of local design partners.

Finally, our view of designing for the emergence of sociomaterial practices has implications for how practitioners should treat the challenge of reproducing or scaling successful interventions. Thanks to influences from evidence-based medicine (Tomlinson et al., 2013) and development economics (Banerjee & Duflo, 2011), many practitioners espouse the view that one should evaluate global health and ICT4D interventions with randomized trials. This discourse often presumes that, once such experiments have proven technologies to be “effective”, reproducing successful interventions in new settings should be relatively unproblematic, and users should be expected to comply with the mandates of the evidence base. It has become relatively easy to critique the technological determinism implicit in this perspective, yet such critiques and the maxim “context matters” do not amount to a coherent alternative vision of more appropriate ICT4D design and implementation. By framing ICT4D interventions more holistically as complex practices, advancing the notion of designing for the emergence of sociomaterial practices, and embracing design research frameworks such as ADR, we contribute to such a holistic and pragmatic approach.

7 Conclusion

By conducting ethnographic fieldwork and inductively analyzing our data, we identify six overlapping activities through which designers may guide the emergence of sociomaterial practices. We analyze designing for the emergence of sociomaterial practices using the metaphor of imbrication, which highlights the gradual and iterative process by which human and material agencies intertwine and come to produce relatively stable sociomaterial practices. Extending prior studies of imbrication, we use the notions of practice breakdown and material back talk to offer a more fine-grained and forward-looking view of prototyping and ongoing design-in-use. We draw attention to a wider range of materials and emphasize that IT artifacts imbricate not only with worker activities but also with material infrastructure. We also highlight a wider range of human agencies. Specifically, we recognize the agency of technology users as well as the limited yet consequential agency of technology designers.

As we move from inductive insights to more prescriptive guidance, our work has three particularly salient implications. First, in contrast with most of the literature on sociomaterial practices, we endorse the forward-looking stance of the original design research paradigm. In other words, IS researchers need not restrict themselves to developing new theoretical lenses for making sense of IT artifacts. They can also undertake the iterative work of designing for the emergence of sociomaterial practices and developing prescriptive design knowledge. Second, in embracing ADR, we stress that such design research should not exclude or be limited to the design researchers’ own conscious decisions. It should also be open to the contributions of participants and responsive to the complexities, breakdowns, and concrete instances of material back talk that inevitably arise in practice. Third, we highlight an opportunity for future ADR projects to engage sociomaterial practices as a domain of intervention and conceptual reflection. This

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engagement will entail examining how “the social” and “the material” become constitutively entangled to produce sociomaterial practices. These points are particularly relevant when it comes to explaining what exactly ICT4D practitioners have accomplished when they claim to have reproduced successful interventions in new settings.

By drawing on and contributing to the literature on sociomaterial practices, we engage a rather philosophical project concerned with challenging the conceptual separation of technology, work, and organization (Orlikowski, 2007; Orlikowski & Scott, 2008). Yet, our contributions to ICT4D are ultimately more pragmatic in nature. The implementation bottleneck in global health has made it increasingly obvious that context matters and that we sorely need coherent, alternative perspectives on more appropriate ICT4D design and implementation. We hope that practitioners will reflect on notions of imbrication, practice breakdown, and material back talk to sharpen their perceptual capacities, and, ultimately, design for the emergence of sociomaterial practices with greater nuance.

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References


Appendix A

Photographs played an important role in our fieldwork and helped the first author, who conducted fieldwork, convey a detail-rich sense of the field to the second author, who served as a critical outsider during analysis and writing. When presenting our work, we often received feedback that photographs convey something important about our case that is distinctive in IS and organizational scholarship. Given the special issue’s concern with exposing the mainstream IS research community to distinctive features of global development initiatives, we publish the following images as an online appendix.

Figure A1. A Vaccine Fridge

A nurse holds two typical analog thermometers above an open vaccine fridge. Behind the tray of vials, ice has accumulated on a cooling element. Temperature readings might be inaccurate if the temperature sensor were placed against the ice or the cooling element.
To the right of the fridge, a propane tank for when the electrical grid goes out. On a stool to the left of the fridge, a TempTracker Device. On the far left, a grey cooler for storing vaccines to be used during a single day. Behind the day cooler, a green bucket with a faucet—the only source of water for hand washing at this health facility.

While mobile phones have become widespread in recent years, most information systems in the Kenyan health service are still analog. This outdoor chalkboard is used by community health workers and public health officers to track immunization rates in a particular community.
Facility staff is expected to record fridge temperatures on charts such as this at 8am and 4pm, seven days a week. Here, the 13th, 14th, 20th and 21st (weekends) are blank, a common occurrence observed during clinic visits.

This photograph shows the public area in front of a typical rural clinic. As usual during morning hours, a small crowd awaits services.
Figure A6. A First Generation TempTracker Prototype
In this prototype device, an Android smartphone sits inside a hard plastic case, with one wire running to an electrical outlet and one to the temperature sensor inside the fridge. The metal “cages” and locks were added during implementation as part of the prototyping process.

Figure A7. A Second-generation TempTracker Device
This image features the second-generation prototype and the other pieces of equipment distributed along with it, which included laminated standard operating procedures, a trouble-shooting guide, a surge protector, a cage, locks and keys, hooks for placing the temperature sensor within the fridge, plug adaptors, airtime, SIM card, and form for registering the SIM card.
Figure A8. Rough Roads and Floods
Poor roads and floods often delayed the first author’s journeys to rural facilities. Such transportation challenges are an ordinary feature of Kenya’s rural immunization program and can be particularly problematic when facilities need emergency assistance.

Figure A9. Results From a Test of the Algorithm for Filtering Electrical Noise
This figure displays the results of a test of the TempTracker algorithm for filtering noisy electrical signal. Blue depicts unfiltered, while green is filtered. A few seconds into the test, multiple halogen lights and a wall heater were turned on near the TempTracker device, and the unfiltered blue signal became less precise as stray electrical signal was picked up by the headphone jack. Figure courtesy of Nexleaf Analytics.
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