A Feminist HCI Approach to Designing Postpartum Technologies: "When I first saw a breast pump I was wondering if it was a joke."

Catherine D'Ignazio
Emerson Engagement Lab
Boston, MA, USA
catherine_dignazio@emerson.edu

Alexis Hope
MIT Media Lab
Cambridge, MA, USA
alexishope@gmail.com

Becky Michelson
Emerson Engagement Lab
Boston, MA, USA
becky@elab.emerson.edu

Robyn Churchill
Clinton Health Access Initiative
Boston, MA, USA
robyncnm@gmail.com

Ethan Zuckerman
MIT Media Lab
Cambridge, MA, USA
ethanz@media.mit.edu

ABSTRACT

In recent years, the CHI community has begun to discuss how HCI research could improve the experience of motherhood. In this paper, we take up the challenge of designing for this complex life phase and present an analysis of data collected from a design process that included over 1,000 mother-submitted ideas to improve the breast pump, a technology that allows mothers around the world to collect and store their breast milk. In addition to presenting a range of ideas to improve this specific technology, we discuss environmental, legal, social, and emotional dimensions of the postpartum period that suggest opportunities for a range of additional supportive technologies. We close with insights linking our findings to ongoing discussions related to Feminist HCI theory, crowdsourcing, and participatory design.

Author Keywords

Motherhood; Feminist HCI; Human-Centered Design; Crowdsourcing; Breastfeeding; Postpartum

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

"Hi! I wanted to cry out HOORAY when I read that you were tackling breast pumps!! I'm a working mother of an 8 month old and have been in the medical device industry for some time. When I first saw a breast pump I was wondering if it was a joke." - Mother 8770

CHI'16, May 07-12, 2016, San Jose, CA, USA. ACM 978-1-4503-3362-7/16/05.
http://dx.doi.org/10.1145/2858036.2858460

Motherhood is a complex life phase that brings with it physical changes, changing relationships, new responsibilities, and shifting notions of personal identity. Especially in the early phases of parenting an infant, the nature of this role can pose many challenges for families struggling to adjust to new realities. Mothers[1] of infants can suffer from social isolation, physical exhaustion, elevated stress levels, and postnatal exhaustion [22]. At the same time, motherhood can be exciting, joyful, and emotionally enriching.

One of the most significant experiences a mother may have in the postpartum phase is breastfeeding. Breastfeeding is on the rise in the U.S. and across the world and is recognized in public health policy as the ideal way to feed a newborn baby [30]. According to the Centers for Disease Control and Prevention (CDC), 79% of mothers initiate breastfeeding in the United States [16]. In the developing world, 39% of children less than six months old are exclusively breastfed, according to UNICEF [47]. The World Health Organization (WHO) recommends breastfeeding for at least the first two years of a child's life [30], and increasing breastfeeding rates in low and middle income countries has been a target of many NGOs as a step toward meeting Millennium Development Goal 4 to reduce childhood mortality [5]. Researchers believe that breastfeeding within the first hour of birth could eliminate 20% of the total 2.8 million annual infant deaths [28]. National policy recommendations are in place in many countries [8, 6]. However, there are numerous challenges for mothers to initiate and sustain the breastfeeding relationship, and by 6 months only 18.8% of American babies are exclusively breastfed [16]. The U.S. Surgeon General has identified the most common barriers to breastfeeding as: 1) Poor social and family support, 2) Embarrassment, 3) Lactation Problems, 4) Employment and Child Care, and 5) Barriers Related to Health Services [48].

[1] In this paper, we use the term "mother" expansively to denote all female and gender-variant parents with a particular focus on those who are breastfeeding and pumping.

Technologies are playing increasing role in the experience of all aspects of motherhood, including breastfeeding. Prior HCI work has explored how digital technologies can improve the breastfeeding experiences of mothers. Feedfinder [10], created through a user-centered design process, is a location-mapping mobile application designed to help women find, review, and share public spaces amenable to breastfeeding. This work argues for designers of public health technologies to focus on community-level interventions rather than focusing solely on an individual.

Milk banks, which collect, screen, and distribute human milk, are a community-level solution to increase the availability of breast milk. Some mothers cannot supply breast milk to their babies for a variety of reasons; for example, if they have a communicable illness, or the infant was born prematurely and has a gastrointestinal disorder. The infrastructure needed to ensure that milk is safe for consumption may not be available in every country, and recent HCI work has sought to create low-cost, decentralized technologies for milk pasteurization in developing countries [18].

Beyond breastfeeding, other recent work has sought to design technologies to combat social isolation faced by mothers of new infants [26], help expectant mothers share information about their pregnancy with an intimate social group [31], and introduce communication tools for homeless mothers at an emergency shelter to connect with support staff and learn about resources [36]. We intend for our research to contribute to this ongoing conversation and body of research related to motherhood and HCI. A 2013 workshop at CHI argued that motherhood is an under-explored transitional life phase that could be better supported by digital technologies [11]. This workshop highlighted earlier HCI work related to motherhood and put forth a research agenda that called for more ethnographic work to explore the everyday lived experiences of mothers, as well as an increase in participatory approaches to designing and evaluating new technologies for mothers.

Our work on HCI and motherhood focuses on a technology that is both an essential and problematic aspect of motherhood in the developed world. In this paper, we take up the challenge of designing for mothers and present an analysis of data collected from a participatory design process that included over 1,000 mother-submitted ideas to improve the breast pump, a technology that helps mothers extract breast milk in the postpartum period. In this paper, we argue that the breast pump is an important and commonly-used technology that has historically been overlooked. By including mothers' critiques of specific breast pump parts, we offer speculative designs for mother- and family-friendly breast pumps. Further, many of the submitted ideas speak to the greater context of being a mother to an infant; they describe environmental, social, and emotional dimensions of the postpartum period and suggest opportunities for a range of additional supportive technologies. As part of our analysis, we address the impact of social pressures, political realities, and societal expectations of motherhood and stigmas of breastfeeding.

The contribution of this work lies not only in specific ideas to improve one fundamental health technology, but in the approach used to encourage nursing mothers—who have many demands on their time and energy—to engage in a participatory design process. We close the paper with insights linking our findings to ongoing discussions related to Feminist HCI theory, crowdsourcing, and participatory design.

BACKGROUND

Our approach is informed by historical trends related to breastfeeding and breast pumping, a commitment to shine light on the experiences of marginalized user groups inspired by feminist HCI, and the participatory lens offered by human-centered design approaches.

The Breast Pump as a Sociotechnical Design Object

There are challenges to initiating and sustaining a breastfeeding relationship that range from education to economics to social and cultural norms to maternal leave policy. The breast pump is a machine that could potentially help mitigate some of these challenges to breastfeeding by helping mothers extract breast milk when they are not with their baby, as in the case of a mother working outside the home or when a mother is with their baby but cannot breastfeed them. Though patents for breast pumps date back to as early as 1854 [41], the contemporary pump was invented by Einar Egnell and Olle Larsson in 1956 [15]. Breast pumps were originally for exceptional circumstances in which babies were too sick to nurse, but companies in the 1990s started designing lighter consumer pumps that were intended for personal use [13]. While exact rates of pumping mothers in the U.S. are not available, a 2005 study found that 77% of mothers who breastfed had also used a pump [25]. Based on the number of women with children under 1 from the Bureau of Labor Statistics (3.1M) [1] and the fact that 79% of women initiate breastfeeding [16], this would put a rough guess at the number of pumping women around 1.8 million. With the passage of the Federal Patient Protection and Affordable Care Act (ACA) in 2010, breast pumps were covered by insurance for the first time, which has led to a boom in demand for pump manufacturers [33] and an increase in new users of breast pumps.

A common refrain from new mothers, which our research confirms, is that many hate breast pumps and the breast pumping experience. This has as much to do with the machine as it does with the lactation environment and with the social and cultural norms around pumping. Boyer & Boswell-Penc's research on pumping in the workplace names this as a "politics of banishment" [15] where pumping is considered an individual problem. Mothers pumping at work must secure permission from employers, secure a space (or find a bathroom, closet, or car), conceal themselves, and discreetly store the resulting breastmilk somewhere where it will not offend colleagues. While public health policy is clear that breastfeeding is a public issue, there is very little family leave policy or workplace policy in place in the U.S. that conceives of it as such. Indeed, the U.S. is recognized as a laggard in maternal health for being the only nation in the industrialized world without any designated maternity leave [29].

Sociologist Linda Blum argues that conversations about motherhood and breastfeeding are not private matters, but

play out publicly the setting of obligations of the maternal body to the larger social body, casting some mothers as inferior if they do not breastfeed [14]. Women's postpartum experience, particularly regarding infant nutrition, sits at a complex intersection of public health recommendations, federal policy, social and cultural norms, workplace regulations, insurance claims, health care practices, family history and individual experience. Throughout the paper, we make reference to many of these aspects which one might normally consider outside of the field of design, because of the way that they affect and constrain women's experiences of postpartum technologies such as the breast pump. It is also important to note that this paper is focused on the breast pump in the context of the United States, the provenance of the vast majority of our data. At the end of the paper, we offer suggestions for employing a similar methodology in a more global context.

Feminist HCI

While the social, political, and cultural issues make the pump a complex sociotechnical design object, the machine and pumping system are an additional problem and warrant sustained attention from designers. Recent high-profile media stories compare the breast pump to the mobile phone to find it lacking in design, pleasure, and innovation [38, 32]. Boyer & Boswell-Penc assert that there is an opportunity to distribute the breast pump product innovation process and value the voices, experiences, and ideas of mothers themselves [15]. These calls are consistent with feminist HCI, which prioritizes pluralism and participation in the design process [12].

While traditional HCI has attempted to create "universal usability," feminist HCI leverages feminist standpoint theory to specifically engage with user perspectives that are left out of a design regime dominated by Western universalism, including perspectives from women, communities of color, children, low-resource contexts, and the Global South [12]. Because these perspectives are marginal and often overlooked, designers need learning experiences to appreciate the concerns, constraints, and opportunities afforded by them. We made use of the feminist HCI approach in our design process, namely by including and explicitly valuing as expert knowledge the voices and ideas of mothers at every event and throughout this paper. Our work represents what Bardzell terms a "generative contribution" which is "the use of feminist approaches explicitly in decision-making and design process to generate new design insights and influence the design process tangibly" [12]. Here we hope to demonstrate feminism in action, rather than to critique instances of oppression after the fact.

Human-Centered Design Approaches

Historically, the design of computing systems has taken a technology-driven approach, assuming that users will change their behavior to match the dictates of modern technologies [43]. Inspired by Participatory Design (PD), a Scandinavian research field emerging alongside worker rights movements in the 1970s, the field of Human-Centered Design (HCD) asserts that the relationship should be inverted; technologies must adapt and change to match the realities faced by humans [4]. Human-Centered Design practitioners use theories and associated methods that consider a singular human or community's needs, motivations, constraints, skills, and resources at each stage of the design process.

The dataset discussed in this paper was part of a larger design process that included a large public hackathon in which many nursing mothers were in attendance. At the hackathon (which itself is the subject of another research paper [removed for blind review]), we introduced HCD as a lens for participants as they brainstormed potential solutions to problems facing breast pump users. The ideas analyzed in this paper were displayed publicly at this hackathon, so that teams would encounter them throughout their design processes (Figure 1). One of the judging criteria for projects at this hackathon was how well teams incorporated mother-submitted ideas into their design rationale.

Crowdsourcing Innovation

Crowdsourcing is a growing area of investigation for various purposes, including product idea innovation [17], advocacy design [40, 24], and as a research methodology [9]. The data that forms the backbone of this paper was collected through a participatory process that was open to the public (described in more detail in the Methods section). Crowdsourcing as a design methodology has been of great interest to product and system designers in recent years. Not only do these methodologies provide a large volume of data in the form of received responses, but they also make possible research threads that could not be investigated through traditional lab studies [9].

Analyzing large amounts of input, however, can be resource-costly. For example, crowdsourcing has been useful for user error reporting (e.g. to get feedback on transportation and other public services), but auditing and managing this data can be difficult and may even require a team of volunteers [40]. Despite these challenges, crowdsourcing methodologies can add tremendous value to "engender innovative solutions amongst divergent voices" [20] and proactively include the requirements of otherwise marginalized groups of users [24]. Thus, crowdsourcing can be a natural complement to feminist HCI and human-centered design approaches.

While opening up design processes to broaden participation is promising, HCI researchers have begun to focus on strategies to improve the quality of submitted ideas. Although crowds are capable of generating many ideas, they may not reliably generate creative and novel ideas. Chan et. al have found that the quality of user innovation can be improved by integrating expert facilitation along the way, a strategy that is similarly effective at in-person ideation sessions [17].

METHODS

In order to collect an archive of mother-generated innovations, we began with a preliminary event in which we convened around 25 midwives, mothers, lactation consultants, public health researchers, designers and engineers in an open-ended brainstorming session and conversation about the breast pump. We identified five "pain points" about the breast pump which included: 1) Education, 2) Difficulty, 3) Too many parts/Not enough parts, 4) Degrading, and 5) Social Norms. We wrote an account of this event for the MIT Media

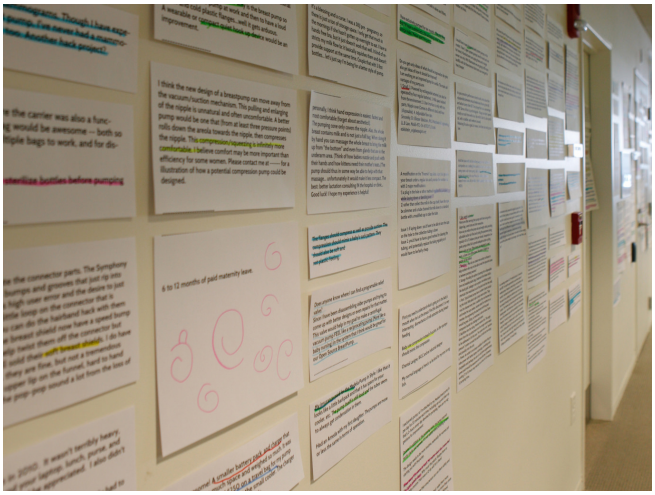

Figure 1. Mother-submitted ideas posted up on the wall at the "Make the Breast Pump Not Suck!" Hackathon at the MIT Media Lab in September 2014.

Lab blog [34] and concluded the post with a call for people to submit their ideas to help make the breast pump "not suck." We included explicit messaging that their responses would be recorded in a public archive and published anonymously on Github. This data was originally collected as an activist intervention to respond to the lack of innovation in breast pump technologies. The mother-submitted ideas were used at a large public hackathon in September 2014.

This paper presents an analysis of the ideas submitted by mothers prior to the event. We believe these ideas can inform further work in the design space for nursing and postpartum mothers, a user-group that may often be overlooked.

Mother-generated Ideas

We received 1,136 ideas for "making the breast pump not suck." Though we did not limit who could submit ideas, we received responses primarily from mothers who described direct experiences of pumping. These ideas were either submitted to our group email address, submitted on a web form for the project, or submitted on Facebook in response to our solicitation. We did not collect demographic data, however, it was clear from their numerous references to the lack of maternity leave, insurance characteristics, and care practices that most women were living in the United States. Responses range in length from very short ideas, *"Moore's Law for breast pumps! Each year breast pumps should be smaller, lighter, and more effective." - Mother 6775*, to ten-point plans and even separate Google documents with matrices [7].

Qualitative Data Analysis

We surfaced the top 20 words and their frequencies related to negative sentiment (Table 1) as a starting point for in-depth qualitative data analysis. The mother-generated ideas were transcribed and analyzed using an iterative, inductive, and grounded approach in order to identify key themes [27] by three researchers who read the data entirely. One researcher then coded the data using Dedoose. Through weekly discussions, we agreed upon 30 unique codes that emerged from the data, 20 of which related to the pump itself. This process was supplemented by our group's many personal conversations at the large hackathon event that we organized prior to data analysis. The interdisciplinary perspectives present at the hackathon lent a nuanced understanding of the problem space and supported our data analysis process.

Negative Word	Frequency
hate	77
pain	60
difficult	48
hurt	31
awkward	28
cry	26
uncomfortable	25
frustrating	21
annoy	18
embarrassing	10
Total	**376**

Table 1. Negative sentiment analysis - Top 10 negative words.

FINDINGS

In this section we first describe the multiple use cases for pumping described in mothers' submissions. Then, we introduce themes emerging from the data related to improving the design of the breast pump object itself. One unexpected consequence of our large data set is that women contributed numerous and occasionally long personal stories about their postpartum experiences. These data contribute towards our final section, where we describe broader insights that have implications for designing technologies and experiences to support postpartum mothers and their babies beyond the pump.

Multiple use cases

My son was born April very unexpected and suddenly at 30 weeks old. He spent 2.5 months in the NICU and fought each day to get stronger. From the first day he was born I began pumping. At the beginning they were feeding him my milk on a q-tip. I was pumping 8-10 times a day to ensure he was getting only breast milk. I would pump at home, at the hospital, even in the car with a manual pump sometime (ouch!). My son is now home (and thank god healthy) but I have returned to work so the pumping continues. I hate it but it is just something you do for your children. - Mother 2840

Returning to work after the birth of a baby is a very common use case in the U.S., where nearly 60% of mothers with children under the age of 1 work [1]. This use case is most often seen in breast pump advertisements and discussed in the popular press. "Back to work" is a phrase that came up often as mothers recounted personal stories about their return to the workplace and the challenges that pumping presented there. However, there are other important use cases for breast pumps that mothers revealed to us. We list these here because mothers in each of these scenarios face different challenges and have different needs.

1. "Back to work"

Some midwives, nurses, and legal scholars refer to the first three months of a baby's life as the fourth trimester of pregnancy [19] [39], where the mother's recovery from pregnancy is physiologically linked with the infant's changing nutritional needs and development. In nutrition research and lactation consulting, the mother and baby form a "dyad", an integrated, symbiotic unit unto themselves [23]. Separating this dyad involves pain and anxiety for both parties. Stories and ideas about going back to work point to this moment as unique and traumatic in the postpartum period.

The comments we analyzed suggest that designers need to note the great variation in workplaces to which mothers return. Women who work in offices prioritize features such as reduced noise that permit them to pump while taking phone calls, for example. Women who work in retail, teaching, medicine, the military, or manufacturing suggested discreetly wearable, completely silent pumps that would permit them to pump at regular intervals even if they were prevented from taking breaks from their shifts. Women who need to travel for their jobs mentioned the need for longer battery life, car adapters, international power converters, more pumping spaces in airports and easier refrigeration and cleaning while on the go.

Across professions, women were dismayed at working environments that make breast pumping difficult, unsanitary and humiliating. This includes private, sanitary places to pump as well as having storage space for pumped milk. *"I am a Registered Nurse, and working mom to 2 girls, now ages 8 and 11. I had to work through 12 hour shifts, while still nursing both girls and it wasn't easy! Lack of privacy, a clean space to set the pump on, a chair to sit down on, and a table or shelf to hold the filled milk jars. - Mother 9207"* Though many of the recommendations were related to the difficulties of the pump and spatial environment, the stigma from coworkers and pressures to work productively are major sources of stress as well. As Mother 9491 shared, *"In the U.S. alone, breast-pumping at work is still very much an unknown phenomenon. I've had male workers (at progressive, high-tech firms) completely oblivious to what this is, and not understand why I cannot just reschedule it to attend another meeting."*

2. Pumping at Home

Mothers often mentioned the challenges of pumping while caring for their baby and possibly other babies (multiples) or older children at home. Women might pump while their baby is present for a variety of reasons: to increase their supply or to set aside extra milk for a nighttime bottle feeding, for example. Mothers who pump at home experience challenges with other tasks and activities that need to take place during the pumping time such as holding their baby, changing a diaper, or getting a snack for an older child. As Mother 8133 says, *"During my pump sessions I can't hold my baby or tend to him because the stupid pump is all sorts of in the way!!!"* Many mothers expressed the desire to multi-task, such as wanting to feed a child with one breast while pumping with the other.

3. Pumping in the Neonatal Intensive-Care Unit (NICU)

According to the March of Dimes Premature birth Report card, 11.4% of babies were born prematurely in the U.S. in 2014 [3]. Breastmilk is the optimal way to feed prematurely born babies, as the biochemical make-up of milk changes when a mother gives birth prematurely and is well-adapted to a preterm infant's nutritional needs [46]. Mothers who have babies in the NICU are often tired, traumatized, and desperate to fulfill the needs of their struggling newborn by pumping breastmilk 24 hours a day even before their milk has fully developed. As Mother 6982 reported, *"Moms with babies in the NICU have to pump around the clock to build supply. It wears you down and you are as exhausted as if your baby was home, except you have the added crap of spending all day at the hospital with your preemie or sick baby."*

These mothers suggested breast pumps you could use while sleeping or lying down, more family-friendly facilities at hospitals, softer and heated flanges, more mobility and hands-free options by default, and pump integration with mobile phones and tracking applications so that mothers could easily and reliably track their milk output. The U.S. leads the developed world in preterm birth rates, and the number continues to remain stubbornly high [37], which suggests that NICU pumping will remain a relevant problem to solve for the foreseeable future.

4. Exclusive Pumping

There is a small but growing population of mothers who exclusively pump, meaning they do not nurse their babies but rather pump milk 8-12 times per day and feed their babies with bottles for sometimes a year or longer. Mothers typically do not plan to exclusively pump but end up doing it because of difficulties with breastfeeding. These mothers share some of the challenges of NICU mothers because of the frequency of pumping. These mothers often spoke about the need for pumping while laying down or sleeping, the idea of pumping directly into storage bags for prompt freezing and the need for mobility, like Mother 2793, who explained: *"Moms who pump exclusively have a need to pump everywhere, not just on their couch. Hands-free and mobile (untethered!) are a must. Many of us also pump in the car (it's the best use of our commute time!)."* These mothers also frequently need to care for their baby while pumping.

Some doctors have called for more research into the impact of feeding infants through exclusive pumping [44]. Whether exclusive pumping is desirable or not from a public health standpoint, we note it here because it is an increasingly common situation that mothers find themselves in and online mother-led communities are beginning to self-organize to support each other [2, **?**]. Designers may wish to consider opportunities to work directly with these communities or to work on interactive systems that can better support women to initiate and sustain a breastfeeding relationship so that they do not have to exclusively pump.

5. Special Circumstances

We heard from mothers with a number of extenuating circumstances and use cases that make breastfeeding and breast pump use challenging. Each of these is a small but significant sub-group that is worthy of further research. These include

larger women, women who have had mastectomies and other surgeries which have altered their breast anatomy, mothers with inverted and bifurcated nipples, and babies born with special needs that make it difficult for them to latch and feed such as cleft palate, tongue-ties or other more rare conditions. Our corpus of comments provides some insight into the needs of these mothers, but a larger sample is needed to explore these challenges in more depth.

Mothers hate pumping

I love breastfeeding my 8 month old but hate pumping. I cried the first time I pumped at the hospital (early latch issues) and struggle still to do it every day. - Mother 2332

Pumping is so isolating. It sucks to have leave friends and family or have to go home in the middle of a party to go pump. - Mother 8697

I cried the first time I used my breastpump ... because it was so belittling and noisy and cow-like. Like probably all mothers, I was very understanding of the benefits of pumping, but I hated every minute of doing it. - Mother 1070

Though our call for ideas was framed in a productive way (”What are your ideas for improving the breast pump?”), many women shared personal stories of distress, anxiety, pain, and isolation around their experiences using the breast pump. In our quantitative analysis, top negative words associated with breast pumping included ”hate”, ”pain” and ”difficult” (Table 1). Just accounting for the top 10 negative words used, there were over 376 mentions across 1,136 submissions. Pumping moms are constantly worried that they are not pumping ”enough,” which could mean enough to nourish their baby, enough to keep their milk supply high, or enough to sustain the breastfeeding relationship for the recommended amount of time. This anxiety, combined with the isolation of pumping (the ”politics of banishment” [15]), prevent women from relaxing, which inhibits the letdown reflex and lowers the amount of milk that can be extracted, contributing further anxiety around the amount of milk pumped. This becomes a vicious cycle such that ”helping mom relax” is a very urgent design problem indeed for pump users. Mothers frequently mentioned feeling isolated, trapped, immobile, ”like a cow”, and strapped to a machine. The sheer negativity of these comments alone should be convincing to designers that there is very much room for improvement.

Mobility, Comfort, Easy Cleaning, & Discretion

We grouped ideas for improvements around top improvements that mothers desired: mobility, comfort, easy cleaning, and discretion. Each of these concepts had hundreds of suggested ideas.

Mobility

It would be nice to have a mobile pump unit that I could wear on a belt or something like that and be able to walk around the house and do things. I didn't always make enough milk during the work day (if I was too stressed) so I would pump in the middle of the night or before work. It drove me nuts to be confined to the chair or bed when I could be using that time to empty the dishwasher or put laundry in or sweep. Or if there was a breast pump I could wear while sleeping, and not worry about my position, that would be great too. - Mother 8976

The most prevalent theme in our analysis was around giving mothers more mobility while pumping often mentioned as ideas for hands-free bras or other wearable options. This encompasses the idea of being able to pump and still do things with one's hands and body, whether that was caring for another child, working on a computer, doing housework or something else. Wearable pumps would have the added benefit of supporting women in different jobs. Six different women proposed a breast pump design that would mimic the discretion and ease-of-use of insulin pumps. Across all of the use cases detailed above, women desired to make use of the time they spent pumping to do other things. Most of the current breast pump models cause spills when leaning back or bending down. Many mothers expressed that they literally ”cried over spilled milk” which is easy to spill during virtually every part of the pumping process.

The time that it takes to pump breastmilk was also a significant issue. Many mothers wrote to us about feeling trapped and unable to accomplish the numerous other things they had to do while pumping. The time it takes to pump also includes the time it takes to go to the lactation space, set up the pump, disassemble the pump, clean the pump, store the milk, and return to the previous location. Another common barrier includes the need to disrobe and re-dress to neatly pump which requires time, privacy, and space. A pumping session may take some women as long as 35-40 minutes when accounting for this time. More mobility was the most commonly mentioned solution to the time problem. Notably, hands-free pumping is a feature that already exists for a couple pumps already on the market. There are also separate accessories one can purchase to use with any pump and even DIY techniques for modifying a sports bra to make any pump hands-free. We address mothers' lack of awareness of existing options and features as an unexpected finding later in this paper.

Other frequently suggested ideas had to do with mobility while outside the home and how the pump is powered. These included much longer cords for powered pumps, longer-lasting and more powerful lithium batteries for battery-powered systems, a notification system for when battery power is low, the ability to charge via USB cords, and a car adapter to plug the breast pump into the car's power system. The final component of mobility included ideas for the portability of the entire system. Women mentioned carrying other items during their day such as backpacks, baby paraphernalia and lunches so adding a heavy pump and portable cooler or ice pack often felt untenable.

Comfort

More than eighty mothers that contributed ideas mentioned that pumping caused them physical pain, either from the suction at the breast or from the position that they had to assume while pumping. They had many ideas for how to mitigate this and make the pump more comfortable. Over 250 separate ideas were submitted about the flanges—the horn-like structures that touch the breasts while pumping that are normally

made of cold, plastic material. Many mothers suggested making them from softer, more pliable material and adding heat which has been proven to help facilitate letdown [45]; *"A lot of women have let down in a hot shower so there should be an option to warm up the flanges so let down is easier"* (Mother 2616). Several mothers also mentioned lubrication for the flanges so that they would create a suction seal at the breast without pulling at sensitive skin.

The "easiest" fix to issues of comfort at the flange site, however, was recommended by numerous women and simply involved including different sizes of flanges by default with the breast pump. Mother 8906 described this situation: *"My pump only came with one size of flange. Luckily, they worked for me but I know plenty of women who had to spend even more money for different flanges. Some of them needed two different sizes!"*

Women wondered why pumping was exclusively based on vacuum suction and couldn't more closely mimic a baby who uses warmth, massage, compression and suction to help trigger letdown. Innovations that address the peristaltic motion of the tongue exist in other industries. One dairy scientist and mother explained that "the combination of pulsation and massage present in habits of calf lactation results in more efficient removal of milk" (Mother 3822). Finally, many mothers suggested that a significant improvement to their pumping experience would be the ability to lean back or lie down rather than pitching themselves forward. The ability to recline would be helpful for pumping that occurs in the middle of the night when many women are exhausted. Women highlighted that hunching forward to pump is particularly challenging for mothers who deliver by C-section.

Easy Cleaning

Could some sort of a self-cleaning mechanism be added? I have the privacy of a storage closet for pumping, but then I need to roam the halls with my breastpump gear to get to the teacher's lounge and clean it (The bathroom just seems so unsanitary!). And of course, then I always hope there are no male coworkers in the room, as they tend to turn a little red in the face at any sign of pumping gear. - Mother 2337

Mothers find the cleaning and sterilization of the many small parts that accompany the breast pump to be an onerous task, particularly when combined with the fact that they may find themselves pumping in cars, closets and bathrooms. They suggested making the whole pump dishwasher friendly, creating a special cleaning basket for pump parts, reducing the overall number of parts (since the small parts are also hard to remember) and designing the parts themselves differently. One of the issues with such frequent cleaning is that parts, particularly the small membranes, tear or break. Since they are specialty items, it not easy to simply run to the drugstore and pick up new ones so women need a back-up pumping option for these occasions. Many mothers suggested that a profound innovation would be a self-cleaning pump.

Discretion

As many people have probably noted, the pump is also very loud. I don't want to pump in my office because the walls are thin and I don't really want people picturing what I'm doing in here when they hear the pump. And when I do it at home, for some reason the sound is like nails on a chalkboard for my husband. - Mother 1427

The analysis yielded the idea that mothers desire discretion and privacy in their pumping experience. 233 submissions made mention of the noise that the breast pump makes as intrusive and embarrassing. The noise is yet one more way that women feel trapped by the pumping experience. Mothers suggested silencing the noise entirely, adding a "white noise" to mask the motor, and adding a cozy to dampen the noise. In her classes, lactation consultant Nancy Holtzman recommends that mothers wrap a towel around the pump (Holtzman, personal communication).

Secondary themes for improving the pump

Several secondary themes that emerged from our analysis. While these ideas were not as frequently suggested by mothers, they represent important areas of consideration in designing for certain communities such as low-income mothers.

Better information tracking

Pumping mothers often track to the half-ounce how much milk they produce in each session. They also may track how much milk from the bottle the baby drinks. Parents of multiples may need a way to label and distinguish milk for different babies. Storage bags need dating and labeling. Many mothers mentioned the need for a timer on the breast pump so that they could see how long they had been pumping. There is much room for design consideration of "smarter" breast pumps that could track important information and synchronize it with a mobile device or web-based system.

Shareable pumps

While hospital-grade "closed" systems are made to be shared, many manufacturers recommend that the "open" systems be disposed of for sanitary reasons. Mothers feel this is wasteful for the environment, particularly given the high cost of breast pumps. As Mother 2904 put it, *"This 'open system' bullshit from [company name removed] is ridiculous. You should be able to share a breast pump with minimal attachments required for each user for hygiene purposes."* Regardless of recommendations, there is a thriving secondary market for breast pumps on Craigslist, eBay and other websites [15, 42]. Finally, several mothers mentioned the idea of standardized parts, so that pumps might work together across brands.

Affordable and "out-of-the-box" readiness

Women felt that pumps should be accessible to all. Mother 5257 shared a common idea: *"Make pumps where moms can pass them on to friends. Not everyone can afford them, and every mom should have access."* One mother even proposed a pump lending library in every community. Many women felt that a consumer device that costs upwards of $200 should come with everything that you need, instead of having to purchase additional parts and accessories. They mentioned needing to purchase differently-sized flanges, hands-free bras, a carrying case, additional bottles, back-up parts, and extension cords. While pumps are now covered by insurance, these add-ons are not, making them unaffordable for many mothers.

Smarter and more personalized pumps
Women had many creative ideas to make breast pumps as intelligent as their other devices. These included the previously mentioned information tracking features, as well as voice-activation and customizable sucking patterns (*"Customisable suck pattern! I can customise the vibrate on my phone but I can't customise the pump on my pump? What's that about?!"* - Mother 5009). These also included ideas to integrate the pumping experience with online communities and information to counteract isolation as well as more sophisticated ways to connect with one's baby through media, sound, smell and touch in order to promote relaxation and letdown.

DISCUSSION

In this section we integrate the themes that emerged from our analysis with three aspects of Feminist HCI theory: "ecology", "advocacy", and "participation." We also discuss how crowdsourcing can be a viable method for wide-scale participatory design work that has a Feminist HCI agenda. While our study focused on the breast pump, these methods and findings have implications for designing other breastfeeding supportive technologies, interactive information systems for the postpartum period, and novel, networked support communities for postpartum women and families.

Ecology and Advocacy

Postpartum technologies such as the breast pump participate in what feminist HCI characterizes as an "ecology" [12]. "Ecology" in feminist interaction design "integrates an awareness of design artifacts' effects in their broadest contexts and awareness of the widest range of stakeholders throughout design reasoning, decision-making, and evaluation"[12]. It is clear that women's postpartum experience sits at a complex intersection of public health recommendations, federal policy, social and cultural norms, workplace regulations, insurance claims, health care practices, family history, and individual experience. This is a complex space where designers need a deep understanding of some of the legal, political, and cultural issues at play in order to create technologies that will be widely adopted.

We offer that human-centered design, with its focus on adopting an empathic stance and interacting with stakeholders at every stage of the design process, offers a productive set of methods for navigating complex sociotechnical ecologies by listening to the actual experiences of the users, in our case postpartum women. This method of listening and co-ideating, particularly if it can be done with a large group of people, can often yield unexpected insights into common pain points and overlooked opportunities in the system.

Understanding the ecology of a problem space through individual voices can also yield unexpected insights. One surprising finding from our data analysis is that a great many of the ideas submitted by mothers to our archive already exist on the market. Frequently mentioned ideas included a hands-free bra, a timer to view how long you have been pumping, a pump that you can wear on your belt and move around, a cordless pump with rechargeable batteries, a place to put a picture of your child, the ability to pump into storage bags directly, and so on. All of these features exist already, though not necessarily all in the same pump. We hypothesize that this lack of information points to a gap in the postpartum information and support ecosystem around pumping and breastfeeding from *the perspective of the mother* as women seem to not be aware of products that would better meet their needs and might significantly improve their experience. This lack of information and support is not unique to the issue of breastfeeding and infant nutrition but there are other gaps in support for mothers, especially first time mothers, who on a national survey consistently report feelings of fatigue, lack of confidence, and social isolation [21].

Our efforts at teasing out this ecology resulted in the findings described in the prior section that articulate four different use cases, overwhelmingly negative feelings, and numerous areas for improvement beyond simply the pump object itself. We were surprised at the extent to which our data set of personal voices revealed many of the more systemic challenges faced by postpartum women, many of which are well-documented and supported in the clinical literature. For example, U.S. federal maternity policy (0 months) does not align with federal public health recommendations for breastfeeding (6-12 months) creating what Jill Lapore has termed a "Human Milk Gap" [35]. This is well-articulated by Mother 2783: *Ultimately, no pumping technology can overcome the fact that our society pushes women back to work too early, with loads of supply-dropping stress about how costly childcare is, and until we fix that on the policy front, no pump is going to meaningfully change the landscape of what nursing mothers are up against.*

The feelings of shame, guilt, humiliation and anxiety (26 mothers specifically told us stories about how they cried when they used the breastpump) can be interpreted as individual women internalizing these failings of public policy. Changing the law may well seem to be outside the realm of human-computer interaction. However, we suggest that upon discovering "design problems" in parts of the ecosystem of a sociotechnical problem space, the designer would do well to use those problems as opportunities to guide her thinking about what are the right problems to be solved in the first place. Bardzell's feminist HCI quality of *advocacy* entails serious reflection on how the technologies that one creates can bring about political emancipation and not simply perpetuate (or, even worse, simply react to) the status quo in a world that is not always just and fair. For example, in the case of the postpartum mothers, it may be that the technologies that are most necessary are not actually improved breast pumps but therapeutic community-based mobile apps or networked organizing tools that help women externalize their trauma and channel it into political changes such as demanding lactation spaces at work, better postpartum care, more insurance coverage or additional paid leave.

Listening to individual voices and experiences is a productive pathway towards revealing and understanding these complex ecologies from a designer's perspective, particularly if the context or culture in which researchers are working in is not their own. We assert that taking an ecological perspective

based in feminist HCI means that the designer must be continually questioning her own position in relation to the problem space and employing the quality of advocacy to grasp how any proposed solution is effecting change within that space.

Crowdsourcing and Participatory Design

As described, we used a process of crowdsourcing to solicit ideas via email and social networking sites. In our case, crowdsourcing ideas for improving the breast pump was a way to expand the conversation and fulfill the feminist HCI quality of "participation." Rather than "establish an objective, distant, and scientific relationship with subjects" [12] we sought to collaborate with breast pump users (and several of us are ourselves breast pump users). Our motivation also stemmed from Balaam's [10] recommendation to "design with mothers and babies." Mothers have thought deeply about their needs and have excellent ideas for improving their postpartum experiences.

We have several reflections on crowdsourcing as participatory design to share with other HCI researchers. First, the topic and framing of the invitation to participate matters. Before we published our invitation we held an intimate gathering of mothers, designers, engineers, midwives and lactation consultants to learn more about the problem space and gauge interest. Based on the overwhelming interest and enthusiasm to a blog post after this event, we realized that the breast pump was such a pain point for so many mothers that we had the potential to start a large-scale conversation. We do not think this approach would work for all topics but it fits nicely with the feminist HCI quality of *pluralism* and Bardzell's call to "nurture the marginal" [12]. For marginalized users whose needs have been consistently neglected by mainstream design, crowdsourcing might work extremely well. 196 separate people personally thanked us for consulting them about their ideas because they had never been asked. Some, like Mother 9064, expressed their love for the project and even for us personally, *"I have no ideas. I just wanted to say that as someone whose baby was exclusively fed on expressed milk for the first 8 months of his life ... I love you. It's one of those quietly hellish experiences so many women have, and so few ever mention. This could prevent so much postpartum depression. Thank you, truly."*

Similar to prior research [40], analyzing the large amounts of input proved to be resource-costly. We were unprepared for the sheer amount of responses we received and analyzing the data took a great deal of time. While we tried doing some quantitative text analysis, the stories were ultimately so personal and qualitative that the only way to do them justice was hand-coding them.

In the prompt itself, we sought to position breast pump users in a generative, empowering way—as creators of new ideas for improving breast pumps—rather than simply telling us what they did not like. We took a playful, deliberately non-objective stance by asking people to help us "make the breast pump not suck." This was another way of demonstrating that we were in this predicament together, not distant engineering wizards but caring partners in making things better.

We believe that the audience for the data—where people think their contributions are going—matters. Participants were more likely to contribute because it was clear from our call for ideas that they had a destination and possible output point: the large-scale hackathon that we organized at MIT. This is to say, there was a clear audience on the other end who was going to be paying attention, reading the ideas, and being held accountable to designing with those ideas in mind. We recommend that designers leverage the feminist HCI principle of *advocacy* to think about how to create an audience for the data that they are collecting and how that data might be used to effect change that is meaningful to participants (not just to researchers).

As Bardzell describes, the issue of advocacy can raise some ethical questions about the role of the designer in the problem space. We think this is especially true where crowdsourcing could lend itself to extractive data collection practices in which researchers "extract" data and stories from vulnerable communities without providing them with the insights and benefits from the process. Our final and most key insight is that crowdsourcing with a passionate group of marginalized users lends itself to community building and advocacy. We felt compelled to not simply extract data from pumping mothers but to help build a public conversation in an on-going way. For example, we started a Facebook group "Hack the Breast Pump" in order to support our participants' further discussions and innovations and it is still an active and vibrant community more than 1.5 years after the hackathon. This has raised some critical questions for us. We were not entirely prepared to steward forward a community of breast pump users and hackers. Does every participatory design crowdsourcing project need to have advocacy goals? When does the project end? What resources do researchers need to plan for in advance to make a project both ethical and successful?

CONCLUSION

There is an emerging discussion in the CHI community about how HCI research could improve the experience of motherhood. Technology increasingly influences this complex life phase, from pre-pregnancy to pregnancy, from birth, and into motherhood. This paper contributes to this dialogue by presenting an analysis of over 1,000 mother-submitted ideas to improve the breast pump collected from a human-centered design process that sought to position mothers in the U.S. as the experts in articulating their needs. From this data, we were able to present the main use cases for the breast pump, and ascertain four major design principles for future breast pumps—Mobility, Comfort, Easy Cleaning, and Discretion—as well as a number of secondary areas for improvement. Our data analysis yielded a number of findings that give HCI researchers insight into the broader experience of postpartum mothers that suggest opportunities for a range of other technologies. Designing for the postpartum experience is complex and context-sensitive, as it sits at the intersection of numerous legal, political, social and cultural factors. Human-centered design and feminist HCI offer a way for designers to understand this ecology and increase adoption of new technologies.

ACKNOWLEDGMENTS

We thank all of the mothers who took the time to write to us, and whose ideas we endeavored to treat with nuance and care. We thank our colleagues at the MIT Media Lab, the MIT Center for Civic Media, and the Emerson Engagement Lab for supporting this work.

REFERENCES

1. Bureau of Labor Statistics Data. (2014). http://data.bls.gov/cgi-bin/surveymost
2. Exclusive pumping's growing popularity. By Kate Tuttle for Babble.com. (2007). http://www.babble.com/baby/breast-free-breastfeeding-pumping-vs-bottle-feeding/
3. Premature birth report card | March of Dimes. (2015). www.marchofdimes.org/mission/prematurity-reportcard.aspx
4. Routledge International Handbook of Participatory Design. (2012).
5. WHO | MDG 4: reduce child mortality. (2015). http://www.who.int/topics/millennium_development_goals/child_mortality/en/
6. *Why breastfeed? - Pregnancy and baby guide - NHS Choices*. http://www.nhs.uk/conditions/pregnancy-and-baby/pages/why-breastfeed.aspx#close
7. kanarinka/Breast-Pump-User-Data. (2014). https://github.com/kanarinka/Breast-Pump-User-Data
8. 2015. American Academy of Pediatrics-What the AAP Is Doing To Support Families. (2015). https://www2.aap.org/breastfeeding/policyOnBreastfeedingAndUseOfHumanMilk.html
9. Lisa Anthony, YooJin Kim, and Leah Findlater. 2013. Analyzing User-Generated YouTube Videos to Understand Touchscreen Use by People with Motor Impairments. In *Proceedings of ACM SIGCHI Conference on Human Factors in Computing Systems*. Paris, France., 1223–1232.
10. Madeline Balaam, Rob Comber, Ed Jenkins, Selina Sutton, and Andrew Garbett. FeedFinder: A Location-Mapping Mobile Application for Breastfeeding Women. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (2015) *(CHI '15)*. ACM, 1709–1718. DOI: http://dx.doi.org/10.1145/2702123.2702328
11. Madeline Balaam, Judy Robertson, Geraldine Fitzpatrick, Rebecca Say, Gillian Hayes, Melissa Mazmanian, and Belinda Parmar. Motherhood and HCI. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (2013) *(CHI EA '13)*. ACM, 3215–3218. DOI: http://dx.doi.org/10.1145/2468356.2479650
12. Shaowen Bardzell. Feminist HCI: Taking Stock and Outlining an Agenda for Design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (2010) *(CHI '10)*. ACM, 1301–1310. DOI: http://dx.doi.org/10.1145/1753326.1753521
13. Emily Bazelon. Milk Me. (2006). http://www.slate.com/articles/life/family/2006/03/milk_me.html?nav=navoa.
14. Linda M. Blum. *At the breast: Ideologies of breastfeeding and motherhood in the contemporary United States*. Beacon Press. (2000). http://books.google.com/books?hl=en&lr=&id=7YYGuVeSdaMC&oi=fnd&pg=PA1&dq=info:YfszT7UWm5gJ:scholar.google.com&ots=KTYOfhmCT9&sig=RbQ41y7e_5kR4PGo-V-SUrQHFno
15. Kate Boyer and Maia Boswell-Penc. A feminist technology, or (yet)" More Work for Mother"? In *Feminist Technology*. University of Illinois Press. (2010).
16. Obesity Division of Nutrition Centers for Disease Control {and} Prevention, Physical Activity. Breastfeeding Report Card 2014. (2014). http://www.cdc.gov/breastfeeding/pdf/2014breastfeedingreportcard.pdf
17. Joel Chan, Steven Dang, and Steven P. Dow. 2016. Improving crowd innovation with expert facilitation. In *Proceedings of the ACM Conference on Computer-Supported Cooperative Work*.
18. Rohit Chaudhri, Darivanh Vlachos, Gaetano Borriello, Kiersten Israel-Ballard, Anna Coutsoudis, Penny Reimers, and Noah Perin. Decentralized Human Milk Banking with ODK Sensors. In *Proceedings of the 3rd ACM Symposium on Computing for Development* (2013) *(ACM DEV '13)*. ACM, 4:1–4:10. DOI: http://dx.doi.org/10.1145/2442882.2442887
19. Jill Cohen. The fourth trimester. 61 (2002), 26–27.
20. Clara Crivellaro, Rob Comber, John Bowers, Peter Wright, and Patrick Olivier. 2014. A Pool of Dreams: Facebook, Politics and the Emergence of a Social Movement. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, Toronto, ON, Canada.
21. E. Declercq, Carol Sakala, Maureen P. Corry, and Sandra Applebaum. New mothers speak out. (2008). http://childbirthconnection.org/pdfs/new-mothers-speak-out.pdf
22. Eugene R. Declercq, Carol Sakala, Maureen P. Corry, Sandra Applebaum, and Ariel Herrlich. Listening to Mothers III: Pregnancy and Birth; Report of the Third National US Survey of Womens Childbearing Experiences. (2013). http://scholar.google.com/scholar?cluster=3052768560955248876&hl=en&oi=scholarr
23. Christine M. Dieterich, Julia P. Felice, Elizabeth OSullivan, and Kathleen M. Rasmussen. Breastfeeding and Health Outcomes for the Mother-Infant Dyad. 60, 1 (2013), 31–48. DOI: http://dx.doi.org/10.1016/j.pcl.2012.09.010

24. Carl DiSalvo, Illah Nourbakhsh, David Holstius, Aya Akin, and Marti Louw. 2008. The neighborhood networks project: a case study of critical engagement and creative expression through participatory design. In *In proceedings of Participatory Design Conference*. 41–50.

25. Sheela R. Geraghty, Jane C. Khoury, and Heidi J. Kalkwarf. Human milk pumping rates of mothers of singletons and mothers of multiples. 21, 4 (2005), 413–420. http://jhl.sagepub.com/content/21/4/413.short

26. Lorna Gibson and Vicki L. Hanson. Digital Motherhood: How Does Technology Help New Mothers?. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (2013) *(CHI '13)*. ACM, 313–322. DOI: http://dx.doi.org/10.1145/2470654.2470700

27. Barney G. Glaser and Anselm L. Strauss. *The discovery of grounded theory: Strategies for qualitative research*. Transaction Publishers. (2009). http://books.google.com/books?hl=en&lr=&id=rtiNK68Xt08C&oi=fnd&pg=PP1&dq=info:MDPDpCn0F7MJ:scholar.google.com&ots=UVxUSh2EYL&sig=N3A1tcNDvQKCreSzDFJDcYZb8Zw

28. Leith Greenslade. *The Biggest Missed Opportunity in Child Survival...Breastfeeding*. (2014).

29. Hall, Katy and Spurlock, Chris. Why Working Families Could Be Better Off In Sweden. (2013). http://www.huffingtonpost.com/2013/02/04/maternity-leave-paid-parental-leave-_n_2617284.html

30. Bernardo L. Horta, World Health Organization, and others. *Evidence on the long-term effects of breastfeeding*. WHO Geneva. (2007). http://www.quenoosseparen.info/documentos/LMlargoplazo.pdf

31. Mary Hui, Christine Ly, and Carman Neustaedter. MammiBelli: Sharing Baby Activity Levels Between Expectant Mothers and Their Intimate Social Groups. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems* (2012) *(CHI EA '12)*. ACM, 1649–1654. DOI: http://dx.doi.org/10.1145/2212776.2223687

32. S. Mitra Kalita. How come there's an iPhone 6 but breast pumps are stuck in 1.0? Quartz. (2014).

33. Sarah Kliff. The breast pump industry is booming, thanks to Obamacare. (2013). http://www.washingtonpost.com/news/wonkblog/wp/2013/01/04/

34. MIT Media Lab. The Media Lab Make the Breast Pump Not Suck Hackathon: by Catherine DIgnazio, Center for Civic Media. (2014). https://medium.com/@medialab/the-media-lab-make-the-breast-pump-not-suck-hackathon-513fad8bc451

35. Jill Lapore. Baby Food. (2009). http://www.newyorker.com/magazine/2009/01/19/baby-food

36. Christopher A. Le Dantec, Robert G. Farrell, Jim E. Christensen, Mark Bailey, Jason B. Ellis, Wendy A. Kellogg, and W. Keith Edwards. Publics in Practice: Ubiquitous Computing at a Shelter for Homeless Mothers. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (2011) *(CHI '11)*. ACM, 1687–1696. DOI: http://dx.doi.org/10.1145/1978942.1979189

37. Joyce A. Martin. United States vital statistics and the measurement of gestational age. 21 (2007), 13–21. DOI: http://dx.doi.org/10.1111/j.1365-3016.2007.00857.x

38. Martin, Courtney E. and Cary, John. Shouldn't the Breast Pump Be as Elegant as an iPhone and as Quiet as a Prius by Now? (2014). http://parenting.blogs.nytimes.com/2014/03/16/shouldnt-the-breast-pump-be-as-elegant-as-an-iphone

39. Saru M. Matambanadzo. Fourth Trimester, The. 48 (2014), 117. http://heinonline.org/HOL/Page?handle=hein.journals/umijlr48&id=125&div=&collection=

40. Aditi Misra, Aaron Gooze, Kari Watkins, Mariam Asad, and Christopher A. Le Dantec. 2014. Crowdsourcing and Its Application to Transportation Data Collection and Management. *Transportation Research Record: Journal of the Transportation Research Board* No. 2414 (2014), 1–8.

41. Orwell H. Needham. 1854. Breas. (1854). http://www.google.com/patents/US11135 Cooperative Alassification A61M1/06.

42. Noelle Crombie. The Oregonian/OregonLive. Market for used breast pumps booms but how safe are second-hand pumps? (2008). http://blog.oregonlive.com/themombeat/2008/12/_medela_one_of_the.html

43. Sharon Oviatt. Human-centered design meets cognitive load theory: designing interfaces that help people think. (2006), 871–880.

44. Kathleen M. Rasmussen and Sheela R. Geraghty. The Quiet Revolution: Breastfeeding Transformed With the Use of Breast Pumps. 101, 8 (2011), 1356–1359. DOI: http://dx.doi.org/10.2105/AJPH.2011.300136

45. Jan Riordan and Karen Wambach. *Breastfeeding and human lactation*. Jones & Bartlett Learning. (2010) http://books.google.com/books?hl=en&lr=&id=eNHQA7VZLvcC&oi=fnd&pg=PP2&dq=info:8dHzFx1LSMEJ:scholar.google.com&ots=gIL7Z8SwEn&sig=5jSSNC6WAASdNCfUPWb2DZcPpb4

46. Mark A. Underwood. Human Milk for the Premature Infant. 60, 1 (2013), 189–207. DOI: http://dx.doi.org/10.1016/j.pcl.2012.09.008

47. UNICEF. Nutrition. (2015). http://www.unicef.org/nutrition/index_24824.html

48. Office of the Surgeon General (US and others. The Surgeon General's Call to Action to Support Breastfeeding. (2011). http://www.ncbi.nlm.nih.gov/pubmed/21452448