1 Introduction

1.1 Executive Summary

In terms of overall child development, the years from birth to age five are the most important. In many countries around the world, these years are also the most dangerous. Each year in the developing world, millions of children under five die due to preventable causes such as inadequate sanitation, insufficient medical care or a lack of clean water. Healthcare organizations have identified the five main dangers to children in this age range as malaria, diarrheal disease, pneumonia, complications during pregnancy, and complications during birth. Creating a solution for even one of these problems has the potential to slash child mortality rates by a significant margin.

Alongside our partner, the UNICEF Innovation Unit, our team of four engineering students from Stanford University and four multidisciplinary students from Aalto University is determined to fight child mortality. Our team visited Nigeria, a country with child mortality rates among the highest in the world. The team travelled in two parts in different times, but came to one conclusion: the biggest challenge, in fact, is the large number of mothers who never visit the health centers, thus not having the right knowledge about child health nor access to medical care. This is a result of a lack...
of access and long distances to the healthcare centers, the lack of trust in the health system and sometimes cultural issues that prevent women from leaving their house.

To tackle this problem we developed a solution to bring the healthcare services closer to the mothers. This is achieved by CareSquare, a portable healthcare station the health worker can carry as a backpack to communities. To achieve the highest impact, our product focuses on the three biggest problems with child healthcare in Nigeria: low vaccination rates, malaria and diarrhea. With the CareSquare the healthcare worker is able to give vaccinations, distribute malaria and diarrhea medication, and share information about taking care of the child with the mothers in their everyday environment. To increase the trust between the community and the healthcare system, our solution also includes a contact person from the community, who informs the community when the healthcare worker is coming and also joins on the actual day to help with the organizing.

The CareSquare will close the gap between the healthcare system and its users that currently exists. It will help to increase the vaccination rate of Nigeria (which is alarmingly low at 63%) and also help to fight malaria and diarrhea. In the future the CareSquare can be modified and used to save the lives of children in other contexts in the developing world.
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1.4 Glossary

**3rd world country** - A nation with a low living standard, undeveloped industrial base, and low Human Development Index (HDI) relative to other countries.[4]

**Camping toilet** - See Porta-john

**CareSquare** - Clinic-in-a-backpack to deliver vaccines and basic healthcare to communities

**CEP** - Critical Experience Prototype. A prototype testing experience that if to fail would make the whole product to fail.

**CFP** - Critical Function Prototype. A prototype testing one function that if to fail would make the whole product to fail.

**Chamber pot** - A self-contained waste containment device for home use that does not require external plumbing to work. The waste must be removed and taken to another site for processing.

**CHW** - Community Health Worker. In Nigerian context a person working in the community health care center, providing diagnosis, prescriptions and health education. Has a minimum education of 2-3 years.

**CHEW** - Community Health Extension Worker. In Nigerian context a younger community health worker, whose job includes going to the community and meeting the mothers and pregnant women at their homes and asking them to come to the health care center. They also have the education minimum of 2-3 years.

**CTG** - Cardiotocography. Technical means of recording the fetal heartbeat and the uterine contractions during pregnancy.

**CT scan** - It’s a medical imaging procedure that utilizes computer-processed X-rays to produce tomographic images or ‘slices’ of specific areas of the body. It’s also known as X-ray computed tomography, computed tomography (CT scan) and computed axial tomography (CAT scan).

**End User** - The person who will use the product.

**EFM** - Electronic fetal monitor. A machine used to observe baby’s CTG.

**Exclusive Breastfeeding** - The baby will not receive any other form of nutrition except the breastmilk of the mother.

**Genset** - Engine-generator, a machine used to generate electricity.

**HDI** - Human development index. It is a composite statistic of life expectancy, education, and income indices to rank countries into four tiers of human development.

**IMCI** - Integrated Management of Childhood Illness. It’s an integrated approach to child health that aims to reduce death, illness and disability, and to promote improved growth and development among children under five years of age. It includes both preventive and curative elements that are implemented by families and communities as well as by health facilities.

**Lye** - Corrosive alkaline substance, commonly sodium hydroxide (NaOH)
NGO - Non-Governmental Organization.

NaOH - Sodium Hydroxide. Highly alkaline, used in making soap.

Neuvola - Finnish maternity clinic focusing on mother and child health.

OCR - Head circumference. Measurement used to monitor baby's development.

Onchocerciasis - Disease also known as “River blindness”. Caused by an parasite and unhealed will result in blindness.

Outhouse toilet - “Dry toilet”. The waste is not flushed away with water, but collected in a container, pile or a pit.

Ownership - A feeling of responsibility, commitment and pride that a person can have towards a physical object or a project.

PCR - Polymerase chain reaction; a method used to generate thousands or even billions of copies of a small DNA sequence.

PHC - Primary Health Center. The smallest unit of healthcare system in Nigeria (and in most other countries). PHCs in Nigeria are equipped with the most basic healthcare facilities and staffed mainly by CHWs and CHEWs with a visiting, supervising medical doctor.

Porta-john (or porta-potty) - A small, portable camping toilet that does not use water (typically uses plastic bags or concentrated disinfectant/deodorizer solution).

UN - United Nations. World's largest, foremost, and most prominent international organization. The stated aims of the United Nations include promoting and facilitating cooperation in international law, international security, economic development, social progress, human rights, civil rights, civil liberties, political freedoms, democracy, and the achievement of lasting world peace.

UNICEF - The United Nations Children's Fund. United Nations Programme that provides long-term humanitarian and developmental assistance to children and mothers in developing countries.

Scalability - The ability of the product to be implemented in other third-world communities and countries worldwide.

WHO - World Health Organization is a specialized agency of the United Nations (UN) that is concerned with international public health. WHO is responsible for the World Health Report, a leading international publication on health, the worldwide World Health Survey, and World Health Day (7th-April of every Year).
2 Context
2.1 Need Statement

In 2011, 6.9 million [1] children under five years old died and over 70% of the deaths were preventable. The five main causes of under-five deaths are pneumonia, diarrhea, malaria, preterm birth complication and complications during the birth (birth asphyxia), which is shown in Figure 2.1-1. While under-5 mortality is way below one percent in developed countries, in many parts of the developing world, especially in Sub-Saharan Africa, the figure is above ten percent reaching almost twenty in the worst locations [2].

![Figure 1: Top five causes of preventable child deaths in 2011](image)

Since the year 1990 under-five mortality has dropped globally from 12.4 million to under 7 million but the rate is still way too slow to reach the United Nations Millennium Development Goal to reduce under-five mortality by two-thirds from 1990 by 2015. Hundreds of NGO’s have been working for decades to solve the problems that cause under-five deaths. The challenge is that the problems are interconnected and fixing one problem does not create sustainable change for the
better. Also, solutions proven effective in developing countries fail to show the same effect when applied to developing countries, as they do not respond appropriately to local context.

Recently, solutions that are based on inclusive innovation creating ownership by local communities have proven to be successful. The key is to find the right intervention points and use the local assets and resources rather than importing solutions from different contexts.

**2.2 Problem Statement**

The challenge for our team is to develop a solution that will eliminate totally or in part one or more of the five main causes of under-five deaths. The solution needs to be backed by novel user insights and a proof-of-concept prototype tested in the real context. We also need to develop an accompanying business model and create a clear point of view on stakeholder involvement (roles, responsibilities, etc.) The solution needs to be open-source, scalable and sustainable in the longer term.
2.3 The Design Team

Tushar Malhotra  
IDBM (International Design Business Management)  
Masters student,  
Aalto University  
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I am passionate about technology - in particular, in reducing the friction between technology and its audiences, and in combining design, technology and business to solve wicked problems. I enjoy ideation, conceptual design and modeling (platforms, ecosystems, processes, products and services), software development.

I am constantly looking forward to bring my skills and passion to challenging and ambiguous problems including, and especially those at the intersections of multiple disciplines.

I aspire to make a difference in the world in the spheres of education and sustainable existence and development.

Skills: Conceptual Design, Theory / Model Development, Program / Product Management, Software Engineering

Blake Reece  
Mechanical Engineering Graduate Student,  
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I was raised in Albuquerque, New Mexico, where I also graduated with my B.S. in Mechanical Engineering from the University of New Mexico. I am interested in all types of design, but I am specifically interested in sustainable design as it applies to products being used or produced today. Outside of my engineering career, I enjoy watching baseball, playing golf, cooking, traveling, and simply hanging out with friends.

Skills: CAD (Solidworks, ProEngineer), FEA, CFD, Matlab, machine shop experience, and composites design and fabrication.
Inkeri Niinimäki  
**Information Networks Masters Student, Aalto University**  
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I believe that technology has a great opportunity to bring happiness to the world and this is my main motivation for the work that I do. I got into human-centered design (HCI), because I want to get to know and try to understand different kinds of people and cultures, and HCI enables me to do that. I am in love with Japan and Japanese culture, and I spent the last year in Tokyo studying emotions and design in Tokyo Institute of Technology. My hobbies are drawing, running and reading. My dream is to own a fluffy dog.

**Skills:** Human-centered design, User Experience, Java, HTML, Cross-cultural studies

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Hanna Poranen  
**Industrial and Strategic Design, Aalto University**  
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I am very passionate about my studies and enjoy working on challenging design projects. I have been part of service design as well as product design projects. Past 1.5 years I spent in China, Beijing studying vehicle design in Tsinghua University. I feel that design belongs to all. It can and should be involved in all areas of life.

**Skills:** Industrial and strategic design, Product design, Service design, Transportation design, Prototyping, Cross-cultural work

---

Janna Rodriguez  
**Mechanical Engineer Graduate Student, Stanford University**  
jannar@stanford.edu

I grew up in Merced, and I am interested in the functionality of simple and efficient products and designs. I am fascinated by affordable, beautiful and action-ready products that can be implemented quickly and rapidly produce results all over the world. And when it’s all said and done I want the owners or the beneficiaries of these products to look at and touch these products and be proud to own it.

Juhana Nurmio
Industrial Engineering and Management Masters Student, Aalto University
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My passion is to combine scalable technology entrepreneurship and social value creation. I want to develop solutions that solve real problems and take mankind forward. I got my interest in product design while I was working for Aalto University to develop entrepreneurship education. I was familiar with the business side of entrepreneurship and I wanted to complement my skills with product design. I enjoy travelling and meeting new people. It is the journey that matters - not the destination.

Skills: Business model development, Strategy, Service management, Communication, Project management

Noel Spurgeon
Mechanical Engineering Graduate Student, Stanford University
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After completing my BSc in mechanical engineering at Rose-Hulman Institute of Technology, I packed up and moved to the west coast to follow my passion for design. I love making things that are beautiful, useful, and elegant, and believe that a well-executed design can change the world. I love discovering connections between different disciplines, and enjoy incorporating these discoveries into the design process.

Skills: Adobe CS, Python, C, mechatronics, composite construction, SolidWorks, and machine shop

Rohan Maheshwari
Mechanical Engineering Graduate Student, Stanford University
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I was born and raised in Delhi, India. I attended BITS, Pilani (India) for my undergraduate studies in Mechanical Engineering. I worked on a couple of cool projects (India’s 1st humanoid robot, etc.) and started a company with friends during my undergraduate studies, and I came here immediately after graduation. I’m always interested in designing and developing stuff that works (mostly...including some hacks!), philosophizing, and anything that challenges the intellect.

Skills: C/C++, Python, Prolog, MATLAB, Qt, MRDS, Autodesk Inventor Professional
2.4 Corporate Sponsor

The corporate sponsor for this project is the United Nations Children’s Fund, also known as UNICEF. Formed in 1946, UNICEF’s main goals are to work with governments and other organizations to overcome the obstacles that poverty, violence, disease and discrimination place in a child’s path. UNICEF’s work is carried out in 191 countries through country programmes and National Committees, while the headquarters are located in New York City.

Specifically, this project is being carried out in conjunction with the UNICEF Innovation Lab Network. This network works to stimulate and facilitate the adoption of innovative approaches throughout UNICEF. The network is growing and currently UNICEF Innovation labs are located in Denmark, Kosovo, Uganda and Zimbabwe.

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3 Design Requirements
The design requirements are based on given requirements that were handed out in the design brief at the beginning of the project and discovered requirements that the team has uncovered during the development process. The activities that led to the discovery of these new requirements were need-finding, benchmarking and prototype testing (Figure 3.0.1).

Figure 3.0.1: Design requirement flowchart
## 3.1 Given requirements

A number of requirements are inherent to a successful project dealing with a need in the third world. These inherent requirements include the requirements mandated by UNICEF in our project brief as well as those requirements that, though not explicitly stated in the brief, are implied in the brief if a successful solution is to be developed. These requirements are listed in the chart below.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>The solution will significantly reduce or completely eliminate deaths of children under 5 years old related to one of the five main child killers (diarrhea, malaria, pneumonia, pregnancy complications, birth complications).</td>
<td>The solution needs to deal with the main killers of children. A measure is needed to evaluate success as part of a continued campaign to lower childhood mortality rates. The solution must reduce the number of deadly cases due to one of these issues, but the solution must be given time to be implemented within the target nation.</td>
</tr>
<tr>
<td>The solution must be scalable to different locations.</td>
<td>The solution must be scalable to have an impact in more than just one small region of the world. Under-5 mortality rates are high throughout the world, and effective solutions must be able to be implemented on a global scale.</td>
</tr>
<tr>
<td>The initial investment cost of the solution must be low.</td>
<td>Any solution that is not very low cost will not access the lower tiers of the target societies. It needs to be available to all potential users with no regard to income or social status.</td>
</tr>
<tr>
<td>The need for maintenance must be low.</td>
<td>In the 3rd world setting, the maintenance is often even a bigger problem than the initial purchase, due to logistics and availability of spare parts.</td>
</tr>
<tr>
<td>The solution must be open source.</td>
<td>An open source solution, meaning free distribution and access to the products design and implementation details, allows increased collaboration in the field and can lead to more opportunities. This can also increase the impact of the solution as it can be implemented by different organizations.</td>
</tr>
</tbody>
</table>
3.2 Discovered requirements

During our field studies in Nigeria and while building Care Square prototypes we discovered several requirements that would be critical to our design. In the below tables we have listed them together with specific metrics and rationale.

3.2.1 Functional Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>The product must enable the CHW to vaccinate a significant amount of children in one visit in a community.</td>
<td>A single CHW has to be able to vaccinate up to 25 children (on average 3 vaccinations per child) with one full backpack.</td>
<td>To make a real effect, it’s important to vaccinate as many children as possible. The CHW will not be motivated to walk several kilometers if they can give only a few vaccinations.</td>
</tr>
<tr>
<td>The solution has to be accepted by the community health care extension workers (CHWs).</td>
<td>95% of the CHWs continue to use the product out of their own will after one month of mandated use</td>
<td>If the CHWs don’t see the value of the solution they won’t use it and system will not work.</td>
</tr>
<tr>
<td>The backpack must be comfortable to carry.</td>
<td>9/10 users between heights 150-200 cm, weighs 45-90 kg and ages 18-45 say that backpack felt comfortable to carry for 10 km.</td>
<td>If the backpack is uncomfortable to carry, the health workers are not likely to use the product.</td>
</tr>
<tr>
<td>The backpack needs to serve as a working station</td>
<td>The backpack needs to include working surface, chair and access to needed supplies</td>
<td>To ensure effective use the backpack needs to function as usable working environment</td>
</tr>
</tbody>
</table>
**Functional constraints**

- The solution has to be enforced by the supervisors of the CHW’s or it will not be fully implemented due to the hierarchical culture of Nigeria.
- The primary health centers (PHC) work with relatively small budgets, so the initial cost of the physical solution should not exceed $60 per PHC and the recurring cost should not exceed $5 per PHC, per month.
- The solution must not require significant electricity or clean water.
- The solution must not significantly increase the workload of the community health worker (CHW). Instead it should be integrated into their regular workflows and should make it easier.

**Functional assumptions**

- The existence of a system of community health workers.
- The CHW’s have been professionally trained in community health and medicine for at least 2-3 years.
- There is already an existing system for getting a local contact person from each neighborhood, e.g. Medic Mobile [1], Unicef’s own RapidSMS [2] system or use the same local contact persons that are used in polio vaccination drives.
- Having a local person in the process will increase the mothers trust to the system.

**Functional opportunities**

- If there is need for vaccinating more than 25 children, this can be accomplished by sending several health care workers with several backpacks to the scene.
- If for example VaxTrack[3] hardware is added to the backpack, the documentation can be done electronically, thus increasing the accuracy, receivability and data processing.
- The product could be locally produced and thus create economical impact in the area.
- An open source solution will allow increased collaboration in the field, which could lead to increased opportunities for solutions. This can also accelerate the impact of the solution as it can be implemented by different organizations.
### 3.2.2 Physical Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
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</thead>
<tbody>
<tr>
<td>The size must allow portability.</td>
<td>The backpack can not be bigger than 60x40x30 cm</td>
<td>If the dimensions of the backpack are too big it will hinder the carrying of it.</td>
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<tr>
<td>The weight of the product must be low enough so that it can be comfortably</td>
<td>The backpack should not weigh more than 10 kg when fully loaded.</td>
<td>The maximum weight for carrying backpack shouldn’t exceed 25% of the users body weight to be comfortable [4]. The CHWs must walk up to 5 kilometers a day, so the product can’t be too heavy or it will be unusable.</td>
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<tr>
<td>carried for up to 5 Kilometers.</td>
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<tr>
<td>The backpack must include medicines/treatments to the most common under-5</td>
<td>The backpack should include treatments for 20 malaria cases and 20 diarrhea cases.</td>
<td>If the backpack doesn’t include the treatments to the basic diseases with under-5, that will decrease the mothers trust in the healthcare system.</td>
</tr>
<tr>
<td>sicknesses.</td>
<td></td>
<td></td>
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<tr>
<td>The backpack must include basic first aid kit.</td>
<td>The backpack must include basic first aid kit.</td>
<td>If the backpack doesn’t include the treatments to the basic diseases with under-5, that will decrease the mothers trust in the healthcare system.</td>
</tr>
<tr>
<td></td>
<td>The backpack must include a first aid kit including:</td>
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<td>- bandages</td>
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<td></td>
<td>- thermometer</td>
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<td></td>
<td>- scissors</td>
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<tr>
<td>The product should have a robust structure.</td>
<td>The external structure should survive any drop from less than 1.5 meters.</td>
<td>The product will not be treated in a desirable way all the time. It has to be able to withstand a diverse set of users and accidents.</td>
</tr>
<tr>
<td>Requirement</td>
<td>Metric</td>
<td>Rationale</td>
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</tr>
<tr>
<td>The product must be durable in rain.</td>
<td>The product should have the liquid ingress protection of IP4 from IP standard, i.e. “Water splashing against the enclosure from any direction shall have no harmful effect. Test duration: 5 minutes, Water volume: 10 litres per minute, Pressure: 80–100 kPa” [5]</td>
<td>Season the backpack will face a lot of moisture and if dropped it can be completely soaked for a short period of time.</td>
</tr>
<tr>
<td>The solution must use a minimum of mechanical parts.</td>
<td>Any mechanical part included should be rated for longevity (at last 5 years).</td>
<td>Mechanical components that break are often not repaired in a 3rd world setting.</td>
</tr>
<tr>
<td>The product must have low power consumption.</td>
<td>The solution can require maximum of 30 min/day of electricity.</td>
<td>From our observations in the field it became clear that electricity is quite unstable and scarce resource.</td>
</tr>
</tbody>
</table>

*Physical constraints*

- The materials needed for the making the backpack should be inexpensive.
- The availability of electricity on our context it scarce – there are power cuts that can take hours every day, and some people have to go to specific places outside their home to use electricity.
- The center of gravity of the whole backpack will change after the HW comes home from field, since the vaccination vials are in the waste disposal box when before they were in the cool box.

*Physical assumptions*

- By mass production the cost of the materials and production of the product will decrease significantly.
Physical opportunities

- Local producers can be used. By using the local producers the price of the product will decrease.
- If the product is viewed favorably in the local community, it can increase their own and other peoples appreciation to their work.

3.2.3 Individual Component Requirements

**Vaccine carrier box**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaccine carrier box must keep the vaccinations cold during the time on the field.</td>
<td>Vaccine carrier box must keep 75 vaccination vials (2,5 ml) between 2-8 °C for 24 hours.</td>
<td>The vaccinations are ruined if the temperature goes higher or lower.</td>
</tr>
<tr>
<td>Vaccine carrier box must have enough space for the vaccine vials.</td>
<td>Vaccine carrier box must hold 75 single-dose vaccine vials.</td>
<td>This is an overall system requirement that 25 children can be vaccinated (avg. of 3 vaccines/child).</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaccine carrier box must not be too heavy.</td>
<td>Vaccine carrier box should weigh less than 5 kg when in full load.</td>
<td>The current UN standard in full load weights 5 kg, our solution should not exceed that.</td>
</tr>
</tbody>
</table>
# Vaccine carrier box lid/table

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The objects should stay on top even when the lid is opened and vaccinations are reached.</td>
<td>The lid functions as the health workers working table and some objects might remain in the table between vaccinations.</td>
<td></td>
</tr>
<tr>
<td>49/50 times when a test user opens the lid that has a syringe and vaccination vial on top of it, takes a vaccination from the cool box and closes it, none of the items fall down.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lid must seal the insulation in the cool box.</td>
<td>The vaccinations in the cool box must remain between (2-8 °C) for 24 hours.</td>
<td>If the lid doesn't seal the insulation the vaccinations don't keep the proper temperature and they are ruined.</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The lid must fit under the fabric cover.</td>
<td>Lid cannot extend more than 5 cm above the top edge of the main coolbox.</td>
<td>The lid extends out of the frame, so it cannot be too tall to fit under the fabric dust cover.</td>
</tr>
</tbody>
</table>
### Vaccine carrier box lid/table

#### Requirement | Metric | Rationale
--- | --- | ---
*Functional*

- The vial pockets need keep the vaccination vials separated from the ice.
  - When the vaccination vial is inserted to the pocket, no portion of the vial is in direct contact with ice and the vial temperature should not drop below 2°C.
  - If the vaccination vials are in direct contact with the ice their temperature will go too low and be ruined.

- The vial pockets should keep the vaccination vials inside securely.
  - When the vial pockets are picked up from the vaccine carrier box 10 times during 1 minute, 0 of the vaccination vials fall out.
  - If the backpack is handled roughly or it e.g. falls down the vaccinations don’t drop from the pockets and get broken/uninsulated.

- The vaccinations can be acquired from the cooler pockets with one hand.
  - 19/20 time a test user is able to reach the correct vaccination from the cooler pocket with using only one hand.
  - Another hand is needed to lift the cooler lid, so the pockets need to reachable with one hand.

*Physical*

- The cooler pockets are made of insulating material.
  - The R value of the material must be more than 0.20
  - If the pockets are made of insulating material, it will help the insulation of the vaccinations.
# Disposable Waste Container

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The waste box has to be able to contain all the waste that is created in the field.</td>
<td>The volume of the trashbox should be at minimum 10,000 cm³.</td>
<td>If the waste box doesn’t have room for all the waste created in the community, it increases the risk of the health worker littering.</td>
</tr>
<tr>
<td>The waste box must be easy to assemble.</td>
<td>9/10 users will say that assembling the box is easy after the first time of assembling.</td>
<td>If the box is too hard to assemble, the users are not willing to use it.</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The waste box has to be disposable.</td>
<td>The waste box must be manufactured from 100% burnable material.</td>
<td>Burning is the main way of disposing waste in Nigeria. If the waste created in the vaccination is not disposed properly it can have a negative effect in the communities it is used.</td>
</tr>
<tr>
<td>The waste box has to be easy to store before use.</td>
<td>When stored, the waste box should take maximum 10% of its size in use.</td>
<td>Since the waste box is disposed after every use, the healthcare center has to keep a stock of them.</td>
</tr>
</tbody>
</table>
# Frame

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Metric</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The frame must support the weight of the backpack.</td>
<td>The frame must withstand the weight of 12 kg, without bending.</td>
<td>If the frame doesn't support the weight of the backpack it is easily broken.</td>
</tr>
<tr>
<td>The frame must provide separate support to the coolbox.</td>
<td>The frame must include 2 vertical bars for supporting the cool box.</td>
<td>If the cool box and waste box are not separated, the backpack will collapse when the waste box is removed for use.</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The frame should be light-weight.</td>
<td>The frame should weigh less than 1 kg.</td>
<td>If the frame is heavy, it will increase the total weight of the backpack too much.</td>
</tr>
</tbody>
</table>
## Backpack Fabric

### Requirement

#### Functional

The pockets must be placed in a way so that ease-of-use is maximized while doing vaccinations.

9/10 users say accessing the all the equipment needed to do vaccinations (syringes, needles, cotton, disinfection and band-aid) can be done easily.

For the healthcare worker to be able to do the vaccinations effectively, all the equipment needs to be easily accessible.

### Physical

The outer material must be waterproof.

The product should have the liquid ingress protection of IP4 from IP standard, i.e. “Water splashing against the enclosure from any direction shall have no harmful effect. Test duration: 5 minutes, Water volume: 10 litres per minute, Pressure: 80–100 kPa” [2]

Especially during the rainy season the backpack will face a lot of moisture and if dropped it can be completely soaked for a short period of time.

The outer material must be of light colour.

The hue of the outer material of the backpack should be 7-9 in the Munsell color model. [4]

The light color will reflect more light and decrease heat absorption, and also make it more pleasurable to carry.

The cover must protect the inner backpack from dust.

The cover will protect the inner backpack from 90% of sand that is shot to the backpack with volume of 1 litres per minute and pressure of 10 kPa.

The dust and dirt will eventually reduce the functionality of the backpack (e.g. reduce the insulation) and make the product less pleasurable to use.
4 Design Development
4.1 Development Strategy

The design brief provided to the team was rather broad and encompassed a large and foreign problem space. The key challenge for us entailed exploring this vast and unfamiliar space, narrowing down the scope and identifying potential intervention opportunities before deciding to pursue one (or a few) of them in greater detail. Given this situation, it was important to allow for a longer and wider than usual exploratory phase and utilize a variety of exploration devices and techniques during the project. Accordingly, the team pursued a number of design directions in parallel for a significant time before deciding to converge.

Early on interviews with field experts and desk research provided the team with the basic scaffolding including potential areas of interest and contextually important issues. The team picked some problem / design spaces from among these and went deeper into the same - iteratively identifying needs, developing personas, benchmarking existing solutions (where applicable), evaluating assumptions and refining the understanding via exploratory prototypes. The field trip(s) to Nigeria provided another, greater opportunity for validating our assumptions and corresponding course-correction and ultimately proved to be the turning point in the design process.

The following sections elaborate on the design development process followed throughout the project. However, while these sections present the process in a sequential manner, it is important to realize that the actual process was much more iterative and parallel in nature.
4.2 Need-finding & Context Mapping

Building a good understanding of the target context (including the socio-economic conditions, lifestyles, environment, etc.) was critical for the team to be able to conceive empathetic solutions that would be accepted and effective. Figure 4.2-1 shows an approximate timeline of activities undertaken by our team towards this end.

Starting with desk research on the leading causes of child deaths and reading about the conditions in sub-Saharan Africa, the team quickly moved on to meeting and interacting with over a dozen experts with broad and deep experiences of working in the developing world and, in many cases, with healthcare or children-related issues. These interviews provided the ‘next-best’ opportunity...
to learn about the target context without actually being there. The field trip, originally planned in late fall / early winter, was delayed due to logistical reasons. During the interviews, besides specific details (see appendix 8.1), a number of general / common themes and issues recurred often. These were categorized and helped in informing the initial ‘working-set’ of assumptions for the team to use as the context for building and testing the initial prototypes.

During the field trip to Nigeria (in late Winter), the team had the opportunity to revisit and verify these assumptions and also carry out much richer first-hand observations and interactions with local experts and real target users.

Based on all this, the context map (figure 4.2-2) and the description below summarizes the team’s current understanding of the target context.
4.2.1 Cultural, Contextual and Socio-Economic Issues

Sanitation and Hygiene constantly came up as major challenges in a lot of interviews, and the information was validated on the ground. The problems in these areas are both individual (e.g. lack of knowledge and habits around personal hygiene, hand-washing etc.) as well as systemic (e.g. lack of proper waste management and disposal systems). Sanitation and hygiene are clearly at the root of and aggravate a lot of health related issues.
Role of religion and religious leaders

The team was somewhat startled to discover how big and crucial a role religion and religious leaders play in almost all aspects of the life of people. The opinions and verdicts of religious leaders are trusted and followed much more than those of, say, the government or health professionals. This fact presents both challenges (e.g. there have been instances of hostile religious leaders discouraging immunization) as well as opportunities (e.g. by getting the local religious leaders on board, the success of healthcare programs could be improved to a great extent). In addition to religion also traditional beliefs have a lot of influence - In case of sickness many people seek help from a traditional healer instead of healthcenter.

Figure 4.2.1-4: Traditional healers
Importance of hierarchies and social order

During our trip, apart from religion, we realized that another source of authority and influence in the society derives from the entrenched hierarchies and social order. Community elders and leaders are often the sole access point to their communities and their approval is necessary in order to carry out any activities.

Role and position of women in the society

Another key aspect that came up often and early during the interviews dealt with the role played by women in many cultures and societies in the developing world. In many cases, gender inequality is the norm and women often have a lot of family responsibilities but limited say in most decisions. A powerful anecdote from the field illustrates this point. During our interaction with a community health worker, she narrated how a mother were not permitted to take her severely dehydrated (due to diarrhea) child to the health center by her husband, resulting in the child’s death.

Related to this are also attitudes around family planning. Having more children is viewed as an asset in terms of ‘helping hands’ as well as a hedge against possible child deaths due to various factors. Empowering women is clearly one of the key ways to effectuate change in these societies.
Attitudes towards long term planning and resource prioritization

Due to both economic and cultural reasons, day to day, hand to mouth existence is prevalent and little attention is paid to long-term planning. Also, a lot of people, especially those in the lower social strata tend to accept and / or ignore basic everyday problems (like lack of toilets) and instead aspire for symbolic or luxurious goods and services. For example, a lot of households may not have access to a toilet but would typically have televisions, mobile phones etc.
Lack of trust between health care workers and the community

Although health care workers are generally supposed to be from the communities that they serve, they rarely are. As a result, they are viewed as ‘outsiders’, and people within a community often harbor some degree of mistrust toward them. When a mother can simply go to a traditional healer she’s known for years instead of a CHW, she often will, solely because of the comfort of familiarity. In addition, various rumors plague the health care system, such as those that suggest vaccination causes infertility.
Transportation and infrastructure issues

Since each clinic serves a relatively large region, clinics can be very far away from the communities that they are meant to serve, especially in rural areas. A lack of infrastructure and reliable public transportation means that community members will usually need to go to the clinic on foot. With longer journeys, this can mean missing a full day’s work (and a full day’s pay).

Lack of awareness

The location of the clinics also posed difficulty in terms of awareness in the surrounding community. The further away a clinic is from a community, the less aware that community member will be of its existence. Even if people are aware of the location of a clinic, the knowledge of specific events held by the clinic will not necessarily make its way into the community.

4.2.2 Prevalent Public Health System in Nigeria

Well-trained staff

The primary health centers in Nigeria are staffed by well-trained professionals. The health workers have at least 2-3 years of professional training and the senior workers have substantial work experience as well. In this sense, the quality of available human resources is fairly high.

Suboptimal resources

The facilities at the primary health centers are often inadequate and below par compared to those in the developed world or even compared to private hospitals in the country. However, even these basic, minimal facilities are often under utilized.

Limited reach and accessibility

The primary health centers have limited reach and accessibility due to large distances, poor infrastructure and ineffective public transportation. Often times mothers need to skip a day at work if they want to visit health center. This means that they will lose a day’s pay as well, which can be devastating in already tight economic circumstances.

Ineffective and inefficient information management

While there is plenty of record keeping at the health centers (often, even redundant), most of those records are not utilized in any intelligent manner and the record keeping is, more than anything else, a futile exercise in keeping people busy and filling up paper. There is a great opportunity to reassess and redesign the information that is captured and the workflows defining how it is consumed.
4.2.3 Tenets for Feasible, Scalable and Sustainable Solutions

Community Ownership & Acceptance of Solutions
Almost all of the experts we interviewed mentioned the importance of promoting community ownership of solutions in order for them to be successful over long term. Freebies and aid-only solutions don't help in the long run. An example of these are a lot of toilet projects carried out in sub-Saharan Africa which are now in shambles because of lack of regular maintenance.

Communication Issues
Communication related challenges were brought up as another major pain-point. Many of the interviewees mentioned that local communication in the field is a challenge since in many cultures, people are not as open and forthcoming and often tend to say the ‘right’ or ‘ideal’ things instead of the ‘real’ things.

Intervention Points
In order to maximize impact, identifying the right intervention points is crucial for any solution. In particular, the Community Health Workers (CHWs) often came up as an important intervention group.

Culture Sensitivity & Behavioral Change
In a lot of situations, while there might be a lack of physical and financial resources, it is still possible to have substantial impact by affecting behavior change among the people in a way that respects the local ethos and culture. For instance, this might mean respecting local traditions and being more cognizant and respectful of local practices and ways of life.
### 4.3 Benchmarking

During the fall quarter our benchmarking focused on recent product innovations that addressed the issues of under-5 mortality. Additionally, we benchmarked several UNICEF projects. Our goal was to create broad understanding of the latest developments in the field and of which solutions have worked and which have not. To get an additional perspective, we did a visit to a Finnish maternity clinic to learn about the facilities and practices in a top-notch setting. In the winter, we had a more focused approach to pneumonia diagnostics and information related innovations. We benchmarked different diagnostics methods and recent information projects aiming to enhance data capture and sharing in the developing world. After we decided to focus on bridging the healthcare gap, we benchmarked current ways to tackle the problem and how to bring healthcare to communities.

#### 4.3.1 Product benchmarking

During the Fall Quarter we benchmarked many existing products that were created to reduce child mortality in 3rd world countries. The most notable examples were The Embrace, a low cost incubator (Picture 4.3.1-1), and the LifeStraw (Picture 4.3.1-2), a device that makes dirty water drinkable. The user sucks the water through the straw that purifies the water.

One of key learnings from these were the importance of the affordability of the solution. The Embrace is over 100 times cheaper than a traditional incubator. Another key learning was that no matter how great the technical solution or affordable the product is, if the people are not willing to use it (for cultural or other reasons) the product will fail. This happened to LifeStraw. People did not like drinking dirty water with the straw. In the end, the more traditional “family size” water cleaner became much more popular. The posters of all of the products benchmarked can be found in Appendix X.

![Figure 4.3.1-1: Embrace](image-url)
4.3.2 Project benchmarking

We also benchmarked past and current UNICEF projects. We found a general trend of using mobile technology and SMS to enhance several different processes and information flows from drug delivery to education, e.g., the Rapid SMS framework for dynamic data collection (Figure 4.3.2-1). However, some of the projects didn't include any technical solution. For example, the “Grandmothers promote exclusive breastfeeding” project was able to increase exclusive breastfeeding in Djibouti dramatically just by empowering grandmothers with information about breastfeeding. The comprehensive list of 20 benchmarked UNICEF projects with the key information can be found in Appendix 8.3.
4.3.3 Neuvola - The Finnish Maternity Clinic

One of the most interesting benchmarks we have found is Neuvola. Neuvola is the Finnish maternity system focusing on mother and child health. The reason why we got so excited about Neuvola was the fact that in only five years under-5 mortality dropped from ten percent to four percent after the nationwide implementation of Neuvola system in late 1940’s. It was not because of economic development or more advanced medical treatments.

Neuvola was based on the idea that mother and child need special attention. Neuvola’s main function was to deliver the right information about child care to the mother at the right time and in a personal way. Neuvola focused on three topics: hygiene, nutrition and vaccination.

- **Hygiene:** mothers received information how to wash the babies and what is the right level of cleanliness.
- **Breastfeeding:** mothers were told the importance of exclusive breastfeeding as the source of nutrition for the children. Breastfeeding is the best way to nourish the child and develop the immune system.
- **Vaccination:** Neuvola also educated mothers about immunization and provided the vaccinations for the children.
The Neuvola system also monitors the condition of mother and the child, and they visited Neuvola clinics regularly and often.

Our idea is that could we use the same principles that were used in Neuvola and apply them in a 3rd world context. In Appendix 8.2. we present a "Mobile Neuvola" concept that we explored further.

4.3.4 Mobile healthcare

VaxTrack - Biometric identification to track immunization

While researching and benchmarking solutions and concepts that address various gaps in the healthcare information management space, we came across VaxTrac, a startup funded by the Gates foundation working on using biometric (fingerprint) identification to better track immunization programs and, in general, vaccination supply-chain management. The current solution uses specially made hardware (fingerprint reader for babies) and software running on netbooks but the company is also working on a mobile based version. The core idea behind the concept is to establish a foolproof way of identifying children and linking them to their medical and immunization records.

Backpack used in Home Hospital

For benchmarking for the pop-up clinic Aalto part of the team visited ‘Home hospital’ (Kotisairaala) in Espoo. They offer hospital quality services at peoples homes for people with cancer and in palliative care or patients needing intravenous antibiotic treatment. The fieldwork in Home hospital is done by nurses. They have a custom backpack with them that includes all the equipment they need [Picture 4.3.4-1]. The nurses can contact a doctor by phone at any time.
We learned that in the beginning when there were only few nurses everyone had their own pack, but when the service grew, several nurses uses the same pack. Each refills the backpack after every use and checks that everything is in place. In addition the bags were checked fully every first Tuesday of the month. There was a picture of all the needed equipment and their placement in the wall for checking. Having the backpacks always fully equipped and in the right order was considered not only a efficiency but also a work safety issue by the nurses.

The nurses worked in three shifts and one nurse was all time in charge of allocating the jobs. The nurses would travel by car to meet their patients, taking their bag with them. The nurses felt that the home environment made them have more personal relationships with the patients. The records of the treatment were first kept with paper notes at the field and the nurses would input them in the electronic system when back in the hospital. However in the future there is plan for mobile electronic documentation, but current solutions are too slow.
They key insights:

- Meeting the patients in their own home is more convenient for the patients and creates more personal relationship with the nurse.
- With a mobile healthcare it’s better to focus on few key activities/user groups since it’s impossible to serve everyone.
- All the equipment inside the backpack should have their own allocated perfect fit place in the backpack. This will not only increase the efficiency but the work safety too.
- The needles have to be disposed of in a separate needle disposal box [Picture 4.3.4-2].

Cold Chain Equipment

Cold Chain Equipment is the lifeline for heat-sensitive vaccines. It is essential for safe transportation of these vaccines from the place of manufacturing to the place of field storage and final carriage to the place of immunization. Thus, CFC-free cold chain equipment ensures a pre-determined safe temperature range (-3 to +10°C) for a particular period known as cold life of the product. The cold life period varies according to the product classifications made by the WHO i.e.
for large equipment like cold boxes, the cold life is high whereas for small equipment like vaccine carriers box the cold life requirement is less. The WHO has formulated rigorous test procedures for maintenance of cold life and for overall strength of the equipment and its fittings, to withstand various rough field usage conditions. The equipment has to undergo tests such as a drop test covering 26 drops (all sides, corners and faces) of the box to ensure compliance with rigid WHO standards and requirements. WHO approval is accorded only after successful clearance of all tests by the test laboratories. All manufacturers in this domain have to comply with the stringent WHO specifications and standards.

**Vaccine carrier box (4.3.4-3)**

These boxes are used when community health care workers go on vaccination drives. Current solutions mostly have thick and multiple layers of insulation, thereby rendering a very low proportion of the box's net volume usable for vaccine storage. Average capacity of these boxes is 2.8L, and they usually weigh between 7 and 8 kgs when fully loaded. The most commonly used material for surface and internal lining is high density polyethylene. In some cases, high density polystyrene is also used. For insulation purposes, a low density and highly rigid variant of polyurethane is supposed to give best results.

**Vaccine vial monitor (Picture 4.3.4-4)**

A vaccine vial monitor (VVM) is a thermochromic label put on vials containing vaccines which gives a visual indication of whether the vaccine has been kept at a temperature which preserves its potency. The labels were designed in response to the problem of delivering vaccines to developing countries where the cold chain is difficult to preserve, and where formerly vaccines were being rendered inactive and administered ineffectively due to their having been denatured by exposure to ambient temperature.

The vaccine vial monitor is intended for use on vaccines which may travel outside of the cold chain, but its use on certain vaccines has had an especially notable impact, like Hepatitis B and Polio.

A key insight was that the use of vaccine vial monitors goes a long way in helping health workers remain confident in vaccines being stored outside the cold chain. However, electronic time–temperature indicators can detect all temperature changes, including issues of freezing vaccines which these heat-detecting vaccine vial monitors would not detect.
4.4 Persona Development

Based on our field trips to Nigeria we created two personas relating to our product: a community health worker and a mother. The designed solution must meet the needs of both of them. The community health worker is the one directly using the product, but also the mother’s point of view in the role of receiver of the service must be considered.
4.4.1 Community Healthcare Worker

Grace Adeleye, 27

**Occupation:** Healthcare worker in a semi-rural Healthcare Center

**Education:** Three years of Community Healthcare worker education

**Religion:** Christian (catholic)

**Family:** Married, two kids that go to elementary school

**Think and Feel:**
She loves God.
Family members pay a big role on the decisions she makes.
Sometimes she gets frustrated that she can't help the people in the community as much that she would like to, since many mothers don't come to the health center. Also the lack of equipment and medicines creates frustration. At the end of the day she still loves her job, and enjoys helping others.

**See:**
A lot of mothers come in for malaria. Second most common is diarrhea. There is not enough medicine sometimes and not too much equipment. Sometimes she needs to improvise some of the tests.

**Hear:**
Has heard that the government could provide them with mobile phones in the future.

**Say and Do:**
Treats patients, gives education to pregnant women.
She says that at work she will do whatever her boss tells her to do.
Says that keeps records diligently, because she is told to do so by her boss.
Tries to act professionally and emphatically, but sometimes the frustrations with the job come out for the patients.

**Pain:**
She has a very long commute to the Health Care center.
Not enough equipment, sometimes there are no drugs to give to the mothers.
Salary can come months late. The boss is a drunk.

**Gain:**
Helping people. Having a job and make a living.
4.4.3 Nigerian Mother

Abdulmajeed Ojaditi, 20

**Occupation:** Has a small roadside store in a slum.

**Education:** Few years of primary school, can’t read properly.

**Religion:** Muslim

**Family:** Married, one kid (2 years, female), now pregnant with another one.

**Think and Feel:**
God will take care of her, tomorrow is a better day. Husband makes the final decisions, wouldn’t take the baby to health care center without consulting to him. Also listens to the opinion of community elders. She wants her children to get education. Instead of weekdays she perceives week in relation to ‘Market Day’ when she goes to sell her products in the market.

**See:**
There are no toilet facilities. Having enough money to buy food and gas is a problem. However her husband bought a mobile phone about a year ago.

**Hear:**
Community and family members encourage her to have a lot of children. Many of the people she knows don’t go to the Health Centers. One of her friends even told her that she once walked 2 miles to the nearest Health Center to get malaria medicine for her child, but they didn’t even have the medicine she needed for her. She has heard rumors after the church that the vaccinations can cause impotence. Her mother-in-law suggests her to go to the traditional healer when she has been feeling ill during the pregnancy.

**Say and Do:**
Says that wants to obey the rules of God. She goes to church three times a week. Most of her day is spent doing food for the family and taking care of her store.

**Pain:**
She has a very long commute to the Health Center, over 2 miles and walking is her only mean of transport. If she would walk to the Health Center, she would have the close her roadside shop for the whole day, and thus lose the whole days income.

**Gain:**
Having a lot of (healthy) children is question of honor for the family. Children will take care of her when she is old.
4.5 Sanitation Prototypes from the Fall Quarter

In the fall quarter our team was focusing on diarrhea and consequently in sanitation. In this chapter we briefly go through these prototypes only focusing on the key learnings that have still value, even though we have since changed directions. The full description of each prototype can be found in Appendix 9.2.

4.5.1 Critical Function Prototypes

A Critical Function Prototype (CFP) is a prototype testing one function that if to fail would make the whole product to fail. Along with the Critical Experience prototype, it was one of the first prototypes we made concerning our project. Our team was focusing on diarrhea, so both of the prototypes address the issue of sanitation but from different points of view: the Stanford part of the team focused on creating better sanitation facilities and the Aalto part of the team focused on the educational side of sanitation behaviors.

Dumping the waste

One of the main concerns surrounding the use of an in-home latrine is waste disposal. The unit should be easy to clean and sanitize, and minimize contact with hazardous waste during the emptying process. The more easily the waste slides out, the less contact the user has with the inside of the device, so we decided to focus on this element for one of our CFPs. Using plastic containers (and substitute waste material), we tested several coatings for the interior of the container to see how well each one performed. By noting the amount of residue left over after emptying each container, we determined that silicone-based lubricant was the most effective in preventing waste from remaining in the container after emptying.

Figure 4.5.1.-1: Silicone-based lubricant
Waste separation and dehydration

While solid waste is extremely hazardous in terms of disease, liquid waste is much safer to handle. In addition, liquid waste does not suffer from the emptying issues of solid waste, and is easier to contain so long as the receptacle is watertight. For solid waste, much of the danger in handling it comes when the waste is wet: without moisture, the harmful bacteria inside it die, making it much safer to handle. Therefore, we experimented with waste separation and dehydration in order to find the best method to dessicate the solid waste and make it easier to handle, as well as deal with the less-dangerous liquid waste.

Visualizing Bacteria

We realised that the underlying reason that makes diarrhea such a big problem is caused by peoples behaviour (e.g. not washing hands after toilet). One way to try to affect to peoples behaviours is through education, preferably starting from early age. Our critical function prototype addressed this problem by using a visualization of the bacteria on the children’s hands. This makes them more aware of bacteria and makes them more receptive to the dangers that bacteria can cause and the importance of handwashing. We found that the germ visualization activity, although effective in communicating the point that proper hand washing is important, may be ineffective with children that do not already have exposure to the concept of germs and the importance of handwashing.

4.5.2 Critical Experience Prototypes

Critical Experience Prototype (CEP) is a prototype testing one experience related to the solution that is essential for the solution’s success. It, along with the Critical Function prototype, was one of the first prototypes that we made concerning our project. Our team was focusing on diarrhea, so both of the prototypes address the issue of sanitation but from different points of view: the Stanford part of the team tested the experience of a portable toilet and the Aalto part of the team tested the experience of soap making.

Chamber Pot

One of the main issues associated with an in-home prototype is the experience of the user. Issues such as comfort, ease of use, and the ability to contain odors will all affect rates of adherence. If these issues are not addressed, the device will not be used, and the intervention will not be effective. To test these key elements of the user experience, one of our users lived with a commercially available camp toilet for a week. The chief learning from this prototype was that commercially available camp latrines are not particularly comfortable or pleasant to use, but the smell was well-contained by the lid, and did not impact the user experience to an unacceptable degree.

Making Soap

Many of the context experts we interviewed mentioned that the availability of soap was a problem in many areas of Africa, which naturally leads to poor hygiene. We concluded that if the children could manufacture soap at school that would simultaneously increase the availability of soap and teach the children about chemistry. For our critical experience we tested the experience of creating soap from sodium hydroxide to determine if it is easy and safe enough to be conducted by a group of elementary school children. We found that the soap making activity was economically prohibitive and too dangerous for young children.
4.5.3 Key Learnings from the Fall Prototypes

Although poor hygiene is one of the main underlying reasons to high child mortality rates and the solutions seem simple, we realized that the issue is very complex. While building the toilet prototypes we learned that the solution space was very saturated: there has been literally hundreds of sanitation projects and most of them have failed. In order to succeed, we should have benchmarked tens of them and interview experts from the field. We started to broaden our focus and decide not just to focus on diarrhea and sanitation.

Many of the reasons why many latrine projects have failed are, however, relevant for us even though we decided not to focus on sanitation. We learned how important cultural factors and educational background are. These will be the most important factors that determine human behaviour. Without the right knowledge people simply won’t use the latrine facilities that are provided to them. Another important factor is inclusive innovation. That is, engaging the local communities in the design process and empowering them to be part of the solution. This would increase their ownership over the solution leading to long term benefits.

Taking all this into account, we realized that a simple product intervention possibly does not work. Therefore, in order to find a suitable intervention point, we started to look into system level challenges. This led us to identify information capture and sharing difficulties as one of the underlying reasons that prevent people from taking the right actions.
4.6 Information Management and Pneumonia Prototypes from the Winter Quarter

4.6.1 Dark Horse Prototype

The Dark Horse prototype was a chance for the team to test wild or ‘edgy’ ideas that don’t necessarily completely fit into the focus of the project. The goal of the dark horse mission was to get inspired and obtain unexpected insights.

Measuring Babies

From our earlier benchmarking in Finnish prenatal clinic, Neuvola, we had observed that measuring and recording vital statistic like baby’s weight, height and head circumference was one of the key activities in such clinic. Since in developing countries the mothers access to prenatal clinics is often impaired, our first focus for the dark horse was to find a solution how these measurements could be done at homes even by uneducated mothers.

However we realized that while these growth measurements provided useful information about general health of the baby, they did not offer a solution to the more critical problems faced by children in the developing world. Most of the scenarios envisaged in the target context required immediate, focused attention before things like periodic tracking would be of use.
RadioMama

The motivation behind RadioMama prototype was also to bring the services of the prenatal clinic to the mothers at home via information and education. The device plays messages sent by community health workers to mothers. The messages are information related to mother's and child's wellbeing, actions needed to achieve this and notifications on upcoming health related events (e.g. vaccination days). We created two alternative interfaces: A mobile box that plays periodic messages automatically, without the mother interacting the device in any way with the form-factor similar to a cellphone and hence can be carried around easily by the mother. The other design was more radio-like box that requires active interaction from the mother (e.g. by pressing a button) to hear the messages.

The prototype and the tests failed to yield much substantial or usable insights. The data from testing was inconclusive with mixed responses towards the RadioMama concept overall. However, the prototype did provide good meta-learning for the team about test planning, design and selecting test users. For instance, the test should have been more focussed and better designed and should have been carried out with the right and more users. We managed to have only a few tests within the Design Factory environment - which was not representative of our target context and user group.

Crowdsourcing in Pneumonia Diagnostics

Noticing the proliferation of mobile technology in Nigeria and the lack of medical personnel, we decided that remote diagnosis would be an option worthy of exploration. Since crowdsourcing had already been shown effective in malaria diagnosis [1], we wanted to test if it could be expanded to pneumonia
diagnosis as well. Mothers or healthcare providers would be able to pick symptoms from a list via a phone application, and these symptoms would then be sent to be evaluated by a number of people via the internet.

In order for crowdsourcing to be effective, however, it must be trusted. We prototyped and tested an app to see how much faith a user would have in an application that received a list of symptoms remotely and returned a diagnosis. Assuming that the application would be most useful to untrained users, we tested it on people with no medical background, showing them videos of sick children, some of whom had pneumonia. We found that users were uncomfortable with having to identify symptoms on their own, and had a limited amount of trust in the diagnosis. In addition, since the proliferation of smartphones in Nigeria is still low, the app would have to be designed for future use, instead of being immediately implemented.

Figure 4.6.1-3: Crowdsourcing app prototype

4.6.2 Funky Prototype

A Funky Prototype is meant to be an approximation of the full system without making a costly commitment to any one configuration or technology. It is a low-commitment, rapidly assembled, concept prototype that still allows for objective evaluation and testing, and therefore is often described as a “duct tape prototype”.
The idea for the BabyBook was to build a bridging solution that would serve the following two main purposes:
For the mothers: It clearly communicates what information / events they need to capture and when and offers an interface which makes it simple and encourages regular engagement.
For the CHWs: It provides them all the necessary health indicators they need in a way which can help them make quick local decisions as well as inform aggregations to enable broader, system-level interventions.

We built and tested multiple customized baby ‘calendars’ or ‘books’ where information can be recorded visually. In the BabyBook, one spread would have a calendar view and educational information (e.g. about hand washing or breastfeeding). BabyBook includes stickers that depict symptoms like diarrhea and fever and child’s development stages like the first step and the first word. The mothers would record the symptoms and development stages in the BabyBook by placing the appropriate sticker on the day of occurrence.

We tested the BabyBook with Finnish mothers (Picture 4.6.2-1), and got positive feedback on the concept and idea. However the mothers wished for more self-explanatory symbols for stickers and an opportunity to compare the child’s overall development with the standard values. Based on this feedback we created more refined version of the BabyBook (Picture 4.6.2-2) for testing in Nigeria.

*Picture 4.6.2-1 Testing the BabyBook with Finnish mothers*
In Nigeria we had a co-creation session with the healthcare workers about the symbols for the BabyBook (Picture 4.6.2-3). We learned that they preferred as realistic pictures as possible, rather real photos than symbols. The biggest problem we came across with discussing with the healthcare workers was that many of the mothers that come to visit the center don’t have the concept of calendar. During our later interviews of health workers and mothers in the healthcare centers we however found that neither of them perceived the communication as a problem, and all the mothers had gotten right information. The mothers who make it to the health system are actually in reasonably good hands. We discovered that a much bigger problem is all the mothers who never find their way into the healthcare system.

*Picture 4.6.2-3 Co-creation session with health workers.*

*Picture 4.6.2-2 Refined prototype version of BabyBook*
Pneumonia Diagnostics - Cell Phone Case

After speaking with several doctors from the Stanford medical school, we decided to build something that could diagnose pneumonia in a similar way that doctors do it in the US. This lead to the idea of a cell phone case that integrated several medical instruments: a pulse oximeter, a thermometer, and an app that uses the phone’s accelerometer to monitor breathing rate. The main motivation behind this prototype was to find a solution that required very little training to use. However, based on expert interviews, a smartphone-based solution was not the best for the problem space, but is a contender for the next decade or so, as both access to electricity and smartphones become more available.
After experimenting with highly technical solutions, we decided to explore one that focused on simplicity. We wanted the solution to be based on materials and resources that were currently readily available, but also could incorporate the diagnostic steps used by western doctors. Taking a multi-step approach to diagnosing pneumonia could catch sick children who do not display elevated breath rate. The way this was accomplished was via a card with a slider attached. If a child displayed a symptom, the card was moved to the right. At the end of the list of symptoms, the color-coded location of the slider on the card could be used to make a pneumonia diagnosis.

However, when the card was tested in the field, it was revealed that the healthcare workers had more training than originally expected. Even with the limited resources available at the clinics, they were still able to interpret symptoms and make diagnoses. If such a device were going to be helpful, it would need to accommodate the needs of users with more advanced skills as well.

### 4.6.3 Functional System Prototypes

The Functional System Prototype, as the name suggests, attempts to combine all of the functionalities into a systemic whole (possibly for the first time in the design process), so that technical and experiential issues can be evaluated. It gives a feel for what the final version might look like, but is still a bit crude and assembled of-the-shelf parts.
Health Mapping System

Health mapping system prototype was our first attempt to answer to the biggest problem in the healthcare system we found in our travel to Nigeria - the vast amount of mothers who never find their way to the health centers. To extend the reach of the primary health centers we found the Community Health Extension Workers (CHEWs) to be the closest and promising contact point. They are the ones who go out to the field to reach out to mothers and encourage them to visit the health centers (or immunization drives). However, the way they operate right now is highly inefficient and quite unorganized. We also noticed that while there was a lot of record keeping in the health centers, it was often not actionable. The ‘Health Mapping System’, inspired by a crude locality map which the team saw hanging on walls in many PHCs, is aimed at utilizing these insights (Picture 4.6.3-1).

![Picture 4.6.3-1: Map on the wall of health center that inspired Health Mapping System](image)

The concept was to make the CHEWs more efficient in their operations by helping them plan their outreach activities and also use the home visits as opportunities to collect useful data. Since we had already been thinking along the lines of making information and records more visual, we thought overlaying different kinds of health indicators on a map surface could help visualize data better and aid in making faster decisions. A heat-map of women who don’t visit health centers (based on CHEWs visits) could help the health center in planning their outreach activities bet-
ter, or a heat map showing a high number of diarrhea cases in a given locality on the map could indicate contamination of a local water well.

We built a quick and dirty prototype by hand-drawing a local map on a cardboard and using differently colored Post-It stickers to record the selected health indicators. We had two co-creation sessions with healthcare workers in which we tested and developed the idea further (Picture 4.6.3-2). For the sessions, we used two test scenarios:

1. Visualizing information about mothers who don’t come to PHCs on the map
2. Visualizing diarrhea cases on the map (and possibly signal any emerging epidemics)

The feedback was positive overall and the users clearly understood the concept the benefits. The senior CHWs could also easily see the value such visualized information would provide for necessitating action and in fact offered new, peripheral use cases. For example, the concept could be used to readily communicate information with organizations such as WHO, UNICEF. In the future the Health Mapping System could have also been implemented in a smartphone map thus making the record keeping electronic.

We continued developing the health mapping system also after returning from Nigeria. However we quickly realized that implementing multi layered system required co-operation of too many entities that we no longer had contact with after leaving Nigeria, e.g. the mobile phone companies and government level organizations. We understood that we needed to create more hands-on solution to the problem of getting more mothers to the health center.
For the diagnostic system, we decided to integrate the diagnostic card with a piezoelectric breath sensor to provide both a clearer reading of breath rate and more user confidence in using the card. The breath rate sensor that was developed was a novel use of commercially available vibration sensors, and was extremely low-cost. The advantage of this is that it could potentially be produced as a sticker, and discarded after use. This would cut down on contamination issues that are prevalent in developing countries. The sensor also uses very little power. The processing for the sensor data was done on a computer, but was not particularly computationally intensive, and could theoretically be moved over to a phone or a smaller onboard microcontroller.
For the diagnostic card, we experimented with a number of different configurations. We had several sticker-based interfaces, which used the idea first explored with the slider card of the diagnostic process being represented by visual progress along a line or around a circle. In addition, we also tested a flipbook interface, a multiple choice ‘scantron’ style interface, and a punch card based interface. The idea behind all of these cards was that when a healthcare worker did a diagnosis, they could tear the card in half and give half to the mother. The mother could then keep the slip of paper, which had treatment information printed on the back.

![Three versions of the diagnostic card](image)

Figure 4.6.3-4: Three versions of the diagnostic card

The breath sensor worked extremely well, both in the field and during pre-testing, from a technical standpoint. However, the diagnostic cards suffered from the same issues that the slider cards did. In addition, the healthcare workers were trained and competent enough that a breath rate counter would not be helpful to them in performing their pneumonia diagnoses.

### 4.6.4 Learnings from the Winter Prototypes

Our first winter prototypes were designed to better the information flow between health workers and mothers. However testing these prototypes in the field led us to the conclusion that the problem was not actually the quality of the communication, but that more often than not the communication link was missing altogether. This insight eventually led us to the our final solution.

The direction of pneumonia diagnostics tools came from a suggestion from our corporate partner UNICEF. However even though creating easy pneumonia diagnostics is a problem in some African countries, especially in the ones where the community health workers have very little education, in Nigerian context pneumonia diagnosis was not the most pressing issue and less common than for example malaria and diarrhea. But testing the pneumonia diagnostics tools with the health workers did give us the important insight that they truly had had a good education and they were confident in diagnosis and thus didn't need easier tools for that. Rather the mothers who found their way to the health centers were in good hands, the mothers who didn't were the problem.
4.7 CareSquare: Clinic-in-a-backpack

Overview - Why CareSquare?
As documented above, the exploration of the problem and design space led us to discovering a number of problems and potential intervention points. It was clear, however, that the most dire need, at least in the context where we visited, was to bridge the gap between the existing healthcare system and the communities it was meant to serve. Once the team decided to focus on this need, specific design questions emerged naturally - How could we make healthcare accessible to the people for whom it was out of bounds either due to logistical, social or cultural reasons? How could we make the community health workers - the first and often the only contact point between communities and the healthcare system - more effective and impactful in their work? Which healthcare activity could provide a broad yet concrete entry point into the communities?

CareSquare - a portable, mini health clinic focussed on maternal and child health which the CHWs could carry with them on field visits to provide immunization and other basic health services, is an attempt to addresses these questions. The specific design requirements for the backpack and individual components have already been captured in section (X). In general, the goal was to design a product that would be truly portable, highly durable and would provide the CHWs with a complete kit of tools and supplies to make them effective in the field.

The decision to focus on immunization rather than simply general health care was due to a number of factors. First, immunization rates in Nigeria are extremely low, around 65%. By increasing these rates to 90% over the next 5 years could save $17 billion and 600,000 lives [1]. In addition, vaccination drives are a way to bring healthcare workers to the community on a regular basis, allowing them to form relationships with community members in a context where the community members are comfortable, as opposed to the unfamiliar healthcare center. This relationship will serve to increase trust between community members and healthcare providers. Finally, bringing the healthcare workers into the community with a fully-equipped clinic will allow them to treat some additional illnesses that are not necessarily addressed by a vaccination drive, further building trust.

Figure 4.7-1 outlines the design evolution of CareSquare, the clinic-in-a-backpack, from an early concept to the finished product stage. During the development it was critical to approach the design from a systems perspective work off a common base in order to ensure that the individual components, despite being developed and iterated upon separately, would integrate well within the whole system and fall in place without friction.

The following sections elaborate this system-centric, iterative design development process in detail, going over the development of each of the system components.
4.7.1 Thermally Insulated Vaccine Carrier Box

Cooler Overview

In order to determine the net internal volume for storing vaccines, we referred to the World Health Organization’s publicly available cold chain and logistics tools, such as the Logistics Forecasting Tool, Vaccine Volume Calculator[1]. This tool gives relevant data regarding full immunization of a child, including data regarding the quantity, cost, and frequency of each vaccine, as well as data for vaccinating per unit of population for a local community.

Based on information from these WHO tools, we determined the requirements needed from our coolbox (chapter 3), and thus made design decisions according to our requirements. The main reason we could not simply use an already existing cooler is that all current cooling solutions for vaccines are designed to be kept closed at all times, except when transferring vaccines to a new storage device. This constraint would not allow us to meet our overall system requirement of giving the CHW’s an easy-to-use mobile vaccination tool. Therefore, we developed a cool box that works as part of a larger cooling system, comprised of inner insulation pockets as well. The cool box and inner insulative pockets
Early Thoughts and Prototypes

Early on in the design process, we focused on generating new ideas for how to keep the vaccines cold while having easy access to them as well. Several ideas were tried, mostly focusing on being able to access one vaccine without exposing all of the vaccines to the elements. Several designs of varying complexity were drawn up, and a prototype of a cylindrical and rotating vaccine carrier was created. The idea was that the vaccine cylinder could be rotated to line up with a small opening in the box, therefore exposing a smaller amount of vaccines to the air. It also featured individual vaccine insulation, as seen in Figure 4.7.1-1.

This prototype was well received initially by the team, but the problems with this and other single vial access designs became apparent once the prototype was used and tested. Issues with this type of design included:

- Moving parts were not reliable
- Added a substantial amount of bulk to the cool box
- Individual insulation was not being applied properly, and was actually hurting thermodynamic performance by insulating the vials from each other and the ice.
- Loading individual vaccines prior to leaving the clinic would be problematic

Because of these issues, we looked for an alternative to the single vial access design, thus leading us to the development of the inner vial pockets, which are discussed in more detail in 4.7.3.
Picking an Insulation

With the simultaneous development of the inner pocket design, we were then able to focus research on just the main cool box construction. The goal of the main cool box was to provide long-term cooling and storage. Ideally, if the box was never opened, the cool box would provide enough insulation to maintain the vaccines.

In the initial stages of the vaccine carrier box development, we did an extensive research on cheap, and highly insulating materials. After extensive research, as well as general testing, we decided to use extruded polystyrene (XPS) foam for building the box because of its durability, water-resistance, and low heat conductivity (~0.035 W/mK). Our initial prototype of the box provided accessibility from the front of the backpack by rotating forward from an upright position (Figure 4.7.1-2). But, based on analysis of structural stability, volume optimization, and testing, we realized that it is better to provide access from the top of the bag. Most importantly, access from the top prevents circulative flow that would move hot air into the cooler.

We conducted some rough initial testing to see if the 1” thick XPS would provide ample insulation for our purposes. We placed the cooler in a room at approximately 25 degrees Celsius and filled it with three inner pockets containing sample vials and ice, as shown in Figure 4.7.1-3. The temperature of the vials was measured at t=0, 12, and 24 hours.

Simultaneously, we were also evaluating the insulation on the inner pockets to determine the best design. The best performing pocket, when kept in the cool box for 24 hours, had a temperature of 10.2 degrees Celsius at 24 hours (it was 8.0 and 3.2 at 0 and 12 hours, respectively. This showed two issues: the vials were potentially getting too cold due to direct contact with the ice,
and the vials were not quite lasting for 24 hour, even at room temperature. How the first issue was dealt with can be seen in section 4.7.3. As for the 24 hour issue, the initial testing was simply to see if the amount of insulation was close to the amount we would need. While the temperature did go above 8 degrees, several factors hindered the performance of the coolbox during this testing, including:

1. The lid could not seal properly, which caused a loss of cool air
2. The inner pockets were a rough prototype, therefore they were also not sealed
3. Only 3 vials were placed in the cooler. A full amount of vials would help keep the cooler at a stable temperature.
4. More ice could be placed in the cooler itself

**EPS and Polyurethane vs. XPS**

Though we had chosen XPS foam from earlier testing and research, it was discovered that XPS does not handle radiant heat very well, such as that from the sun. When compared to a simple cooler made of expanded polystyrene (EPS) in the sun (see Figure 4.7.1-4), the cooler made of XPS did not perform favorably. This led to a re-evaluation of potential insulation materials. From research, XPS was supposed to be far superior to EPS in terms of insulative properties from conduction, so we still preferred XPS. However, an alternate material was polyurethane, a foam with an even better R value.

After experimenting with some polyurethane insulation, it was determined that it simply didn't have the functional properties needed for our cooler (waterproofing, durability, etc.), and so we decided to keep the XPS with one design change. We added a radiative barrier insulation, which
is a thin aluminum lining, on the outside of the cooler. When in the backpack, this lining greatly reduces the amount of heat transmitted to the foam through radiation, which greatly increases the insulative properties of the cooler as a whole. The final cooler, with XPS foam and aluminum radiative insulation, can be seen in figure 4.7.1. It is designed to be filled with 2 inner pockets that are packed with ice. The sides of the cooler are supposed to be packed to the top with thin ice packs (<0.75”) in order to maintain the overall cool box temperature.

4.7.2 Lid and working surface

By virtue of being a ‘pop-up’ clinic-in-a-backpack, one of the key requirements of the product was to provide a stable and comfortable working surface for the community health workers. In order to achieve this, a key tactical design decision was made to explore the possibility of utilizing the vaccine carrier-box lid as a working surface in addition to its primary function of providing an effective thermal seal for the box.

From design perspective, there were two related but distinct aspects of the lid that needed consideration namely, (1) the form or structure of the lid and (2) the choice of materials for construction including the surface finish. This section elaborated the design evolution of the lid from both these aspects.

Structure / Form Prototypes

**Hinged, flippable design**

The initial design concept consisted of a pizza-box style, hinged lid. This was primarily driven by the need to accommodate VaxTrac hardware - a 7-inch tablet and a fingerprint reader - within the lid itself. During transportation, the lid would remain closed, enclosing the hardware in the cavity between the top and bottom surfaces. The hardware itself was meant to be fastened to the top lid in custom built slots.

Several problems emerged with this approach e.g. complexity involved with using hinges especially in the given environment and robustness concerns. However, the critical factor that caused us to explore alternate designs for the lid was the fact that the design of the access mechanism for vaccines was changed. The new mechanism was top-accessible (instead of being front-accessible) and required the lid to be removed for accessing the vaccines which would have been
cumbersome with the hinged design. Also, it was decided to forego the integration with VaxTrac solution for a later version of the product due to time constraints. The hinged, flippable design was hence and overkill for the first version in any case.

**Sliding-lid design**

In order to accommodate the design change with respect to the vaccine accessing mechanism (top instead of front, as noted above), an alternate lid design was prototyped. This consisted of the lid being attached to the vaccine carrier box by means of a sliding mechanism which allowed the top surface to be retracted for accessing the vaccines when needed. The sliding mechanism ensured that the lid was still usable as a working surface. However, this design exposed a number of design flaws based on benchmarking and user-testing as noted below:

- **Inadequate thermal sealing:** Incorporating the sliding mechanism in the lid led to less effective thermal sealing of the vaccine carrier box due to small gaps introduced between the box and the lid.
- **Sturdiness / Reliability in the deployment context:** Another concern with the sliding mechanism was its design complexity and robustness especially in our target context, given the exposure to harsh weather and environmental conditions like dust and heat.
- **User testing of the prototype exposed another behavioral design flaw - after retracting the lid to access vaccines, users tended to leave the lid open as it was still usable as a working surface. There was no intuitive cue to guide the users to close the lid.**

**Liftable design with thermal sealing**

In view of the above design issues, the sliding-lid design was foregone in favor of a simpler design with liftable lid. The lid is formed to include a thermal seal that sits in the box cavity, thus providing better insulation. The seal design was borrowed / inspired from that found in the commercially available cold-box that was used for benchmarking. This design, by virtue of being simpler, doesn't involve any moving parts and hence is sturdier and more reliable. Also, since the lid needs to be completely removed from the box and held in one hand like a tray for accessing the vaccinations, it is intuitive to replace it back unlike the sliding mechanism.

The top of the lid is fashioned in the form of a tray with a short wall / fence on all sides to prevent stuff from accidentally falling off the surface.

![Figure 4.7.2-1: Liftable lid with thermal seal and tray top](image-url)
Materials & Surface Coatings

The lid itself is made out of the same XPS foam as the rest of the vaccine carrier box to provide uniform thermal characteristics. However, since the lid is expected to be exposed to much more handling and thus wear and tear during normal use as compared to the rest of the box, it was decided to provide a more durable surface finish for the same. A number of materials and methods were experimented with:

- **Glued styrofoam surface** Pieces of styrofoam were glued onto the exposed surfaces of the lid. The tray walls on the top were made of XPS as well and covered by styrofoam. While the styrofoam worked well as a material for providing a durable lid covering, the use of separately glued pieces was tacky and left the seams exposed.

- **Plasti-dip coating** Plasti-dip provides a durable rubbery coating for a variety of materials and would have had the desired characteristics. However based on our testing, XPS foam was not suitable for the plat-dip coating, which consumed and destroyed the foam.

- **Fiberglass resin coating** Fiberglass resin coating was also tried as another alternative. While the resin provided a durable, hard surface finish on drying, it was easy to peel off and did not have good adhesion to the foam surface underneath.
Monokote is a lightweight plastic coating material used in model-making, especially popular with aircraft modelers. The material is available in form of thin sheets that can be applied and adhered to the model surface by heat-shrinking. The coating was however not found to be durable enough, was difficult to apply in sharp corners and closed contours of the lid and was vulnerable to being peeled at exposed edges.
**Vacuum molded styrofoam shell** Since styrofoam, as a material, offered the most favorable durability and thermal characteristics for our purpose, as already noted above, and the only problem with using it was gluing separate pieces and exposed seams, we decided to mold and vacuum-form a styrofoam shell to cover the XPS lid without any surface joints or seams. This approach worked well overall and provided a surface with the desired finish for the lid.

**Figure 4.7.2-4: Vacuum Molding the outer lid shell**

### 4.7.3 Vial Pockets

As the cooler does not provide enough insulation on its own to keep the vaccines cold for the amount of time specified by the design requirements, they required additional insulation. In addition, the vials must be protected from bumps and drops, as well as organized by vaccination type. In order to accomplish this, a soft organization/insulation structure was chosen, consisting of fabric pockets mounted to a fabric backing.

Two different designs, and several different combinations of material were used in developing the pockets.

**Pocket-in-pocket design**

The pocket-in-pocket design utilized a combination of foam and fabric to insulate and protect the vaccines. A thick, double-layered ‘envelope’ was constructed from a closed-cell foam, sealed around the edges with vinyl. Inside of this outer pocket, a piece of fabric that supported a series of about twenty vial-sized pockets was placed, constructed of ripstop nylon. Behind the nylon was located a flat gel pack of ice, to control the temperature of the vaccines.

This design was ultimately abandoned due to the inefficient use of space and materials. The thickness of the closed-cell foam made each individual vaccine pocket bulky, and only cooling a
single layer of vaccines with each ice pack greatly increased the number of ice packs required to cool the quantity of vaccines the cooler was designed to carry.

**Sandwich design**
For the sandwich design, the outer pouch was abandoned to save bulk. Instead, an ice pack was sandwiched between two pieces of fabric. Each side of the fabric pouch contained rows of vaccine pockets, which were made of an insulative material. This design utilized the cold pack much more efficiently, and was sealed at the top with a flap of neoprene fabric in order to keep the ice packs cold for as long as possible.

![Figure 4.7.3-1: Ice packs inside the finished pockets](image)

**Material choices**
Initially, the pockets consisted of ripstop nylon. While the nylon was durable and moisture-resistant, it wasn’t particularly stiff or insulative. In order to combat the insulation issue, the material was switched to 2mm thick neoprene. However, while the neoprene insulated the vials well from the environment, it also insulated them too well from the ice. A combination of ripstop and neoprene was then used, with the ripstop comprising the back of the pockets and neoprene comprising the front. In an attempt to deal with the puckering caused by the difference in stretch between the neoprene and the nylon, a four-way stretch spandex was tried. However, the spandex was not stiff enough to maintain the shape of the pockets unsupported, so the material was ultimately switched back to ripstop nylon.
4.7.4 Frame

In order to provide an adequate workspace for the health care worker, some sort of table would need to be included in the backpack. In order to minimize the amount of weight added, it was determined that this table functionality would best be obtained by incorporating a solid structure that would support the cool box and lid (and therefore the workspace). By giving the backpack an internal frame, no additional components other than the chair would need to be added, and there would also be the added benefit of providing protection for the less durable internal components such as the coolbox and waste box.

Choosing the Frame Material

The first step in the design development process of the frame was to determine the best material
to be used for the internal structure. Based on the design requirements for the frame, the material needed to provide adequate strength while adding little weight to the overall backpack system. Due to these requirements, three materials were selected because they met the requirements for our frame: PVC, bamboo, and aluminum. Each material was tested by constructing a simple box frame with the dimensions of the backpack. They were then evaluated based on strength, weight, ease of manufacturing, cost, and availability of materials.

The PVC frame was constructed with \( \frac{1}{2}'' \) pipe, with matching fittings at the joints. The test frame bent substantially when loaded (though some of this was due to poorly fitting joints), and was quite bulky in terms of size, thus reducing the amount of space inside the frame. It was also a bit heavy when compared to the other options. Because of these reasons, PVC tubing was not selected.

Several bamboo rods were used to construct the bamboo frame, as well as some thin twine. In order to make the joints, two pieces of bamboo would be wrapped with the twine as tightly as possible, such that the pieces were not free to move. Then, an epoxy was applied (for our test we used wood glue) to the joint, and left to dry. Once the epoxy is hardened, the joint is strong and durable. The idea behind using the bamboo was that it could potentially be a material readily available in Nigeria. It is also lightweight. However, due to the amount of epoxy needed at the joints, the overall frame was somewhat heavy. The joints were also very bulky, once again limiting space, as seen in Figure 4.7.4-1.

The aluminum frame was constructed using long pieces of \( 1/16'' \) thick aluminum angle. Separate straight pieces were cut and then assembled together into a frame using nuts and bolts, as well as steel corner brackets to make the frame sturdy. Even with all of the added hardware, the aluminum frame was lightest, and it was also the sturdiest when load was applied at the top of the frame. In addition, it was the least bulky of the three options, since full tubes were not necessary, leaving the most internal space for the cooler and waste boxes.

**Iterations of the Aluminum Frame**

After choosing the aluminum frame as the most desirable option, iterations began to make the frame more lightweight while maintaining the same rigidity and strength. In order to cut weight, much of the steel hardware pieces needed to be removed. Therefore, a new frame was constructed making use of rivets instead of metal bolts. However, it was difficult to constrain the frame properly when using just rivets, and the rivets were also not designed to take much weight.

In order to deal with these two issues, a frame was developed to minimize the number of separate pieces making up the frame. This was done by bending the aluminum around corners where pos-
sible. In order to further minimize the space taken up by the frame, a smaller piece of aluminum angle was used (1/16” thick with offset sides of ¼” and ½”). These pieces came as 60” long pieces, and could be easily bent once a small 90 degree cut was made to allow the bend (seen in Figures 4.7.4-3 and -4).

By using this method, the two side parts of the frame were now to be constructed as two “hoops” that were bent on four corners and attached by rivets. These two side pieces were attached by two more bent pieces that connected the two sides. Several pieces of flat, ⅜” thick aluminum were used to connect the two side hoops at the top and bottom of the frame as well. These pieces were attached by nut and bolt, as they were also used as a connection point of the bag straps to the frame, therefore they needed to supports the full weight of the bag. The final frame design can be seen in figure 4.7.4-5.
4.7.5 Disposable Waste Container

In order to ensure proper disposal of all the used equipment that the healthcare worker uses during a vaccination drive, we decided to create a waste box disposal system. This box would contain all the waste used during the drive such as syringes, cotton, empty vials, etc. The only item that would not be deposited into the waste box would be the needles.

**A Permanent Waste Container**

Our first idea was to have a permanent waste disposal box that is easy to clean and maintain. This box would be emptied at the end of every vaccination drive and be properly disinfected afterwards. The disinfection process was extremely important for this prototype, since the box contained blood or fluids from the different patients. We spent a significant amount of time researching possible sterilizing materials that would be economically suitable and accessible in Nigeria. While looking through these materials, we also had to consider which of them were compatible with the material of the waste box itself to ensure durability. Finally, from the user side, we had to make sure that the healthcare worker understood the danger of cross contamination if the waste box was not properly sanitized after every single use. At the end we decided that all the requirements were not achievable, and the risk of not properly sanitizing the box was a major concern.

**A Disposable Waste Container (First Iteration)**

In order to avoid the sterilization of the box every time it was used, we decided to move to a disposable waste container.

The idea of doing a disposable waste box created many issues, such as:

- How are the clinics going to get these boxes?
- What happens in the event that they run out of boxes?
- Are these boxes pre-assembled?
- Is cost effective to building these boxes?
- What are the clinics going to do with all the waste?

In order to answer all these questions, we did a study about a self-sustainable and fully recyclable waste box disposable program. The general idea was that when the clinics got their vaccination supplies, they were also going to get their waste disposal boxes. The healthcare workers were going to be trained how to prepare and handle the old boxes and seal them properly to ensure that no hazardous material was going to come out the box. This program would not only help the healthcare workers to get rid of the waste, but also, it was going to benefit different government organizations. Since the return of the empty boxes contain all the used vials per vaccination drive, this process was going to help organizations to track and to count how many children were being vaccinated at once, how many vaccines were been used, and which types vaccines were being administered. Also, the rest of the waste materials, such as cotton balls used to absorb blood, could be used to do random blood test that could track current diseases at specific areas.

The first box we created was made of cardboard, and was about 20cm tall, 36cm wide and 36cm deep. It had a whole on the front of the box to allow the healthcare workers to dispose the waste
without having to physically remove the box from the backpack itself. After a few user interactions, we realized that having the hole on the front side was not convenient and created a hazardous problem since the materials could easily fall out the box as soon as the box was half way full.

**A Disposable Waste Container (Second Interaction)**

After collecting and processing the information from the different users, we moved the hole to the top of the box. This was not only going to allow the garbage to stay inside the box at all times but also when it came time to seal the box and get it ready to be transported, sealing it from the top was easier.

We considered having two holes instead of one to make it more convenient for the healthcare workers and to maximize the space inside the box. It seems that with a single hole, the waste accumulated on the center of the box, and someone must to push it through the sides manually. We were trying to prevent any contact with the waste, therefore, we designed a box that could be easily lifted and shaken by healthcare worker without risking the waste coming out of the box during the process. In order to accomplish this task we tested at least four different lids that we incorporated into the box.

**A Disposable Waste Container (Third Iteration)**

The boxes were going to be delivered at the same time that the vaccinations were going to be delivered, and all of the boxes were going to be flat and unassembled. We created a box that was going to be intuitive to the healthcare worker to put together with a minimum effort on their side. The drawing below shows a piece of the pre-cut cardboard similar to what the healthcare workers would have available at the health center.

![Figure 4.7.5.-1: Four different possible holes for waste box](image)

![Figure 4.7.5.-2: Waste box layout](image)
A Disposable Waste Box (Fourth Iteration)

From our previous designs we learned that the assembly of the box itself was not intuitive enough for any given user. Therefore, we decided to incorporate some info graphics that were going to help the users to put the box together.

Similarly, we discovered that some of the edges were not properly designed and this made it difficult for the users to fold the box properly. We corrected all of these problems and our new unassembled box has infographics and friendly overall design.

4.7.6 Supply Pockets

To vaccinate the children and to provide basic healthcare the Care Square backpack needs storage space that can fit all the required items and that is easy to access while giving the vaccinations. To meet this requirement we first listed all the items needed (Table 4.7.6-1), (Figure 4.7.6-1).
Table 4.7.6-1: Content of Care Square backpack

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vaccination items</strong></td>
<td></td>
</tr>
<tr>
<td>Needles</td>
<td>75</td>
</tr>
<tr>
<td>Syringes</td>
<td>50</td>
</tr>
<tr>
<td>Cotton</td>
<td>50 pcs</td>
</tr>
<tr>
<td>Disinfectant</td>
<td>100 ml</td>
</tr>
<tr>
<td>Sharps disposal container</td>
<td>Capacity for 75 needles</td>
</tr>
<tr>
<td><strong>Other equipment</strong></td>
<td></td>
</tr>
<tr>
<td>Roll bandage</td>
<td>4 rolls</td>
</tr>
<tr>
<td>Cotton pads</td>
<td>4 pcs</td>
</tr>
<tr>
<td>Rubber gloves</td>
<td>6 pairs</td>
</tr>
<tr>
<td>Scissors</td>
<td>1 pc</td>
</tr>
<tr>
<td>Thermometer</td>
<td>1 pc</td>
</tr>
<tr>
<td><strong>Medicine</strong></td>
<td></td>
</tr>
<tr>
<td>Malaria pills</td>
<td>20 x 4 pills</td>
</tr>
<tr>
<td>ORS tablets</td>
<td>20 x 4 pills</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>20 x 4 pills</td>
</tr>
</tbody>
</table>

Figure 4.7.6-1: Care Square content
After we had the list items we knew how big pockets are needed for each item. At this point, the first constraint was the surface area of the sides of the backpack, hence the pockets could not be inside the main bag that was needed for cool box and waste storage. Also the front of the backpack was not an option due to non-optimal weight distribution. The items should be placed as close to person’s back as possible. We wanted to pack the items as compactly as possible because any extra space would make the backpack bulkier to carry.

The second requirement was to create the best possible user experience (see chapter 5.3 Usage Specification) for the community health worker when she is giving vaccinations. The items that are needed during a vaccination process are:

- Needles
- Syringes
- Cotton
- Disinfectant
- Sharps disposal container

Hence, we wanted to place these items on the top of the sides for easy access while sitting behind the backpack.

Taking these factors into account we built a funky prototype (Figure 4.7.6-2) to test the pocket placing. The syringes and needles were placed on different sides so that health worker could easily reach them both at the same time and on different sides of the backpack and as close as possible to the health worker.
Our initial assumptions were very close to right. After conducting user testing (Figure 4.7.6-3) both in Finland and Stanford we decided to keep all the selected items on the top but to change their places with one another. We realized, however, that cotton should be closest because two hands are required to strip a piece. Also the sharps disposal needs to be close and both syringes and needles should be individually packed to enable one-hand-access.

We decided to place other equipment and medicine on the lower parts of the backpack sides because CHWs don’t need to access them as frequently as the vaccination related items. Finally, we placed a neoprene insulated water bottle holder on the left side of the backpack. In the field we observed that CHWs might put their water bottles inside the vaccine carrier box reserved for vaccines to keep the bottle cool. We wanted to prevent this from happening so we included a dedicated pocket.
Figure 4.7.6-4: Final item layout in top pockets
Figure 4.7.6-5: Care Square from both sides showing the supply pockets.
4.7.7 Back Support

In addition to adequate insulation properties, the backpack needs to be ergonomic and easy to carry so that CHWs would adopt it. Taking into account the short time and the focus of our design we decided to try to build the back support using parts from an existing backpack. We detached the entire back facing part including shoulder and waist straps of a hiking backpack.

In the first prototype we built a fabric bag in which we placed frame, vaccine carrier and waste box. The backside of the bag had a “pocket” where the back support fit (Figure 4.7.7-1).
We tested carrying and putting the backpack on and off. We learned quickly that with this mechanism the backpack was way too loose and the ergonomics were terrible. Hence, we decided to figure out a way to attach the back support directly to the frame.

Our initial idea was to attach the back support directly to the frame with the aluminum bar that was part of the back support and gave it an ergonomic spine-shape form. However, we soon discovered that the bar was not strongly attached to the back support itself because it was not designed to bear any load.

At this point, we decided to sew straps to the back support and use them to attach it to the frame. We used six straps (2 at the bottom, 2 at the sides and 2 at the top) to firmly attach the back support to the frame. We tested the ergonomics with 10 kg full load and it felt good enough. The frame was, however, still bit too low and the bottom aluminum bar hit directly to the person's back instead of the back support (Figure 4.7.7-4).
For the final version we adjusted the positioning of the straps and attached them very tightly to the frame. Now the backpack felt almost as good as a normal hiking backpack (Figure 4.7.7-5). To make it even better in terms of ergonomics, we should have decreased the size of the whole backpack but that was not possible due to the space needed to accommodate vaccine carrier and waste box.

Figure 4.7.7-4: Left: First prototype with the back support directly attached to the frame. Right: Frame too low.
Figure 4.7.7-5: Final version of the back support
When choosing the fabric for the backpack we needed it to be waterproof to withstand the rainy season and light coloured to avoid negative effect to the insulation of the vaccine carrier box. For the penultimate prototype we used sand-color 500-denier water-resistant nylon cordura as the fabric. Based on the prototyping with that prototype we decided to use the same fabric, but stronger (1000 denier) for the final version. However, for reasons unknown the color of the fabric we ordered had changed to light green. Since it still satisfied the requirement for color, we used it in the final prototype anyway.

When we had the fabric we created several sketches how the backpack could look (Figure 4.7.8-1). After this, we created a paper patterns (Figure 4.7.8-2) of the backpack on top of the actual frame with all the pocket sizes and colors and brought that to the tailor, who then sewed the final backpack according to that model (Figure 4.7.8-3). We visited tailor four times to guide her with the work and check the progress.
4.8 Future Development

Testing in Nigeria

We didn't get the chance to test our final prototype in the field in Nigeria within this course. To finalize the product testing with real users in the actual context would be a critical next step. We need to test the usability of having to carry the CareSquare to the communities and the vaccination process. Possibly the places and content of the pockets will have to be refined based on the testing. Also the insulating pockets inside the vaccine carrier box are subject to change according to the specific vial sizes used in Nigeria, since for the prototype we were forced to use an approximation of normal vial size. Furthermore, one of our requirements was to make the CareSquare desirable looking for the healthcare workers. For this, several iterations with the actual users would be needed before finalizing the final look and feel of the product.

Design for Manufacturing

Mapping out possibilities of local manufacturing was outside the scope of the project in this course, but when the product would be finally implemented, finding a way to produce the components locally should be one of the main priorities. This has the opportunity to not only to reduce the cost but to create a positive boost on the local economy. However, this might cause the materials and manufacturing processes to be updated based on local capabilities and costs.

Biometric information management with VaxTrack

In the future we would incorporate also biometric documentation tools like the fingerprint recognition of VaxTrack in the CareSquare. VaxTrack is a startup using biometric fingerprint recognition to create more accurate vaccination recording for developing world. Including VaxTrack to the CareSquare would be as easy as adding additional pockets for the hardware (a tablet and a fingerprint reader) in front or on top of the CareSquare. Currently VaxTrack is testing their solution in Benin and could possibly also incorporate testing CareSquare in their own testing.

Unicef Backpack project

Our corporate liaison Unicef is starting an independent backpack project in the near future, and CareSquare will be used as an input for the project.
5 Design Specification
5.1 Overview

While the backpack is designed as a fully functioning system that can be used to conduct mobile immunization drives, the design development occurred as a process of designing several subcomponents that all work together to form the CareSquare. First, we present the whole product that explains how all of these pieces fit together, and then more detailed specifications for each subcomponent. Each of these components has its own set of requirements on top of the requirements relating to the full backpack. Therefore, the design of each was carefully crafted so that we could maximize the effectiveness of a certain function (i.e. cooling, comfort, etc.) without compromising the effect of the system as a whole.

The perspective picture shows the entire product - the backpack workstation (with lid exposed), the waste-box and the portable chair in-situ.

As seen in the figure, the inner structure consists of an aluminium frame which reinforces the external fabric and also provides the scaffolding for the vaccine carrier box and the waste disposal box.

The detailed breakout diagram shows all the components of CareSquare and their relative / schematic positions in the the product including the medical supplies and other contents and where they are placed inside the backpack. The components are covered and specified in greater details in the following sections.

5.2 Product Specification

5.2.1 Thermally Insulated Vaccine Carrier Box

Overview
The vaccine carrier box, as the name suggests, is designed to be a container for the vaccines. Besides the storage, the box is designed to provide superior thermal insulation allowing the vaccines to be maintained at temperatures between 2-8 degree celsius for up to 24 hours.

Materials
The box is constructed using commercially available Extruded Polystyrene (XPS) which has relatively high thermal resistivity (R-value) and better durability, water resistance and weight characteristics than most other insulating materials.
Figure 5.1-1: CareSquare proof-of-concept

Figure 5.1-2: Inner Structure
WORKING SURFACE
1. Lid doubles as a small table to enhance usability
2. Encourages HCW to keep cooler lid closed

COOL BOX
1. Radiant barrier insulation
2. Main coolbox provides 24 hour insulation
3. Essential to maintaining the cold chain

VIAL POCKETS
1. Neoprene pockets keep vaccines cold when lid is opened
2. Two sided, 36 vials in one pouch
3. Vaccines can be easily accessed with one hand

THERMAL PROPERTIES
1. Maintains vials between 2-8 °C
2. Vials last 24 hours
3. Temperature maintained even with frequent opening

NEEDLES
- Disinfectant
- Cotton

MALARIA MEDICINE
- ORS
- Antibiotics

WATER BOTTLE
- Insulated bottle pocket designed to increase comfort for HCW

WASTE BOX
1. Made of cardboard for easy disposal
2. Can be easily assembled on site
3. Enhanced medical waste disposal at mobile sites

NEEDLE DISPOSAL
- Syringes

FIRST AID KIT
- Rubber gloves
- In the pocket lid:
  - Scissors
  - Thermometer
**Form & Dimensions**
The Vaccine box is constructed in the form of a cuboid using 1” thick XPS foam sheet (i.e. thickness of all the walls of the box is 2.5 cms). The other external dimensions of the box are as follows:

- Height - 31.5 cms
- Length - 34 cms
- Width - 22 cms

**Radiant Barrier**
In order to improve the thermal resistance and minimize heat loss due to radiation, a radiant barrier is provided around the box. This is achieved by coating the outer surface of the box with tin / aluminium foil and creating a small (4-8 mm) air gap between the box and the backpack exterior.

*Figure 5.2.1-1 Air Gap Between Frame and Radiant Barrier*
5.2.2 Lid/Working Surface

Overview
The dual purpose lid is designed to provide an effective thermal and weather seal for the carrier box as well as function as a convenient working surface for the health worker.

Form and features
Inner XPS lid with thermal seal: The main inner lid, including the thermal seal is carved out of a single block of XPS foam (2" thick sheet). The thermal seal is designed as a 1" (approx.) extrusion on the bottom surface of the lid dimensioned to exactly fit the inner dimensions of the carrier box. Outer shell including tray-top working surface: The outer shell, constructed by vacuum forming polystyrene, is designed to provide a sturdy, durable outer cover for the XPS lid as well as function as a working surface (in the form of a tray with walls to prevent stuff from accidentally falling off.)

Materials
The lid is fashioned out of 2" thick XPS foam sheet. The outer shell / covering, including the tray top is constructed by vacuum forming a 1/16" Polystyrene sheet. The bottom surface of the lid including the thermal seal, is painted white using a water based paint (multiple coats).

Dimensions
Inner XPS Lid
Length: 33.5 cm
Width: 21.5 cm
Thickness: 5.0 cm (including thermal seal), 2.5 cm without thermal seal

Thermal Seal
Length: 27.0 cm
Width: 15.0 cm
Thickness: 2.5 cm

Outer Polystyrene shell
Length: 34.0 cm
Width: 22.0 cm
Sidewall height
(including tray wall): 5.0 cm
Tray depth: 2.5 cm

Figure 5.2.2-1 Lid Dimensions
5.2.3 Vial Pockets

Overview:
The vial pockets are designed to be a soft storage, protection, and insulation system for the vials. They utilize an internal ice pack in order to maintain the vaccines at a safe storage temperature.

Forms and features:
The vial pockets consist of a ripstop nylon pouch, with strips of neoprene sewn on the sides to form pockets for the vials. The main pouch contains an ice pack, and is closed with an additional neoprene flap. All seams with the exception of the hem of the ripstop nylon are sewn with a zig-zag stitch, and the seams joining the front panels to the side panels are butt seams.

Materials:
Lightweight ripstop nylon, 2mm thick neoprene fabric, nylon thread, velcro, commercially available ice pack.

Dimensions:
Pocket dimensions: 21.0 cm x 26.0 cm x 3.5 cm
Ice pack dimensions: 20.3 cm x 10.5 cm x 2.1 cm
Individual vial slot dimensions: 4.5 cm x 7.0 cm
5.2.4 Frame

Overview
The frame is an internal aluminum box-like frame that is lightweight, weighing about 0.5 kg, and sturdy enough to support the full weight of the cool box and its contents.

Forms and Features
The frame consists of seven separate pieces of aluminum, all attached together either using rivets or small bolts. It uses bent aluminum “hoops” to create the main structure of the frame, thereby reducing the need for hardware in most places. Two solid bars at the top and bottom of the frame allow for direct mounting of the backpack straps, so that the load gets transmitted through the frame.

Materials
The frame consists entirely of two types of aluminum bars. The main frame is composed of 1/16” thick aluminum angle that is offset with sides of ¼” and ½”. Two connecting pieces at the top and also one at the bottom are made of a flat aluminum piece that is 1/4” thick and ¾” wide.

Dimensions

![Frame dimensions diagram](image)

Figure 5.2.4-1 Frame dimensions
5.2.5 Disposable Waste Container

Our disposable waste container was designed to be eco-friendly and our vision is to ensure that government organizations are connected with the healthcare centers at all times.

The Recycle Process:

**The Disposable Waste Box Cycle**

1. Government and other organizations such as UNICEF and WHO send and track a specific amount of vaccines and waste boxes
2. The healthcare worker receives:
   - Vaccines and
   - Flat pre-cut cardboard to make the disposable waste box
3. The healthcare worker uses the vaccines and properly disposes all the waste inside the boxes
4. Government organizations receive all of the waste, recycle the empty vials, and recycle the waste boxes

**Materials:**
We needed to make the waste container out a material that it was affordable and durable. We decided to use cardboard since it is available in Nigeria. Also, the cardboard that we selected can support many times its own weight, since the top layer, the bottom layer provide support for the middle layer. The middle curvy layer act as like a spring or cushion to resist crushing and impact.

**Material of the waste box:**
Three layers of heavy paper called “containerboard”.
5.2.6 Supply Pockets

Overview
The supply pockets accommodate all items in addition to vaccine vials. A complete list can be found from Design Development section, Table 4.7.6-1. The pockets are place to provide optimal working experience while vaccinating. The goals is also to keep pockets as small as possible to reduce the dimensions of the backpack as a whole and make it comfortable to carry.

Forms and Features
All the pockets (except the bottle holder) are rectangle shaped and angled from the front and back edges to make them look smoother (Figure 5.2.6-1). The pockets are closed with velcro. The same velcro can be used to fix the pockets lap-overs while working.

Figure 5.2.6-1: Pockets on the sides of the backpack.

Figure 5.2.6-2: Top view to pockets
Dimensions

**Right side upper pockets**
- Sharps disposal: 20.0 cm x 11.0 cm x 5.0 cm
- Syringes: 20.0 cm x 11.0 cm x 5.0 cm

**Right side lower pockets**
- Malaria medicine: 6.0 cm x 7.0 cm x 3.0 cm
- ORS: 6.0 cm x 7.0 cm x 3.0 cm
- Antibiotics: 6.0 cm x 7.0 cm x 3.0 cm

**Left side upper pockets**
- Cotton: 13.0 cm x 9.5 cm x 5.0 cm
- Disinfectant bottle: 13.0 cm x 4.0 cm x 5.0 cm
- Needles: 13.0 cm x 7.5 cm x 5.0 cm

**Left side lower pockets**
- First Aid: 8.0 cm x 22.0 cm x 3.0 cm

**Left side bottle holder**
- Insulated bottle holder: 7.0 cm (diameter) x 25 cm (length)

Materials
The pockets are made of same material as the backpack. See 5.2.7 Backpack Fabric.

5.2.7  Backpack Fabric and Back Support

Overview
The main function of the fabric is to cover the backpack and protect the inner parts and make it comfortable to use. The supply pockets are also attached to the fabric. The back support ensures ergonomic carrying properties. A back support form a regular hiking backpack was used to build the prototype (Figure 5.2.7-1).

*Figure 5.2.7-1: CareSquare front and back view*
**Forms and Features**

Fabric covers the whole backpack and follows the dimensions of the frame (Figure 5.2.7-2). The fabric forms a bag where the frame, cooler box and waste container fits. The fabric is attached in the frame with velcro (Figure 5.2.7-3). On top of the backpack a lap-over covers the cool box lid. There is also a fabric hatch for waste box.

The back support is attached directly to the frame with six nylon straps (2 x 2" wide on the top and at the bottom - 16.0 cm distance from one another, 2 x 1” on the sides - 19.0 cm up from the bottom). The straps are sewed to the back support and they loop around the aluminum frame (Figure 5.2.7-3).

![Figure 5.2.7-3: Fabric is attached to frame with velcro](image1)

![Figure 5.2.7-2: Backpack fabric follows the form of the frame.](image2)

The back support is attached directly to the frame with six nylon straps (2 x 2" wide on the top and at the bottom - 16.0 cm distance from one another, 2 x 1” on the sides - 19.0 cm up from the bottom). The straps are sewed to the back support and they loop around the aluminum frame (Figure 5.2.7-2).
5.3 Usage Specification

The health worker will start setting up the vaccination station removing the chair from the backpack and placing it behind the backpack. Then she will continue by opening all the pockets. The pockets are designed in a way that they can be kept open so that the health worker doesn’t need to keep opening them during the vaccination drive. She will also take the waste disposal box and place it outside the backpack.

When the health care worker gets a baby to vaccinate she will first disinfect the area of vaccination with disinfection solution and cotton.

Then she will reach for the vaccine carrier box and get the vaccination vial. Since the lid of the vaccine carrier box is also her working area, she is forced to close the lid every time, thus keeping the cold air inside. She will place the vial on the lid.

After that the health worker will get the needle and syringe from the pockets. She will unwrap them and throw the wrappings in the waste box.

She will then assemble the needle and syringe and insert the vaccination from the vial to the syringe. Then she is ready to give the vaccination.

After she has given the injection, the health worker will dispose the needle in a separate needle
disposal box. Rest of the syringe will disposed in the waste disposal box.

In the end the health worker will document the given vaccinations either by traditional paper-based documentation with vaccination cards or by biometric fingerprint tracking.
5.4 Solution

1. Health worker’s work starts at the Primary Health Center where she will check which neighbourhood she is scheduled to visit with her CareSquare.

2. Few days before leaving to certain neighbourhood, the health worker has contacted the community contact person of that neighbourhood. This can be done using locally already used network e.g. MedicMobile [1] or Unicef’s RapidSMS [2].

3. The community contact person will then inform the mothers in her neighbourhood to bring their child for vaccination on the day. Having a familiar person to inform the mothers will increase the trust to the healthcare system.

8. At the end of the day the health worker returns to the health center. She will write report of her day and refill the CareSquare.
4. On the day of vaccination drive the health worker will travel to the community by foot carrying the CareSquare as a back pack. Before leaving to the field she will always check that all the equipments are in place and refills the CareSquare if needed.

5. The healthcare worker and community contact person will meet in the neighbourhood, and the community contact person stays to help set up and run the vaccination drive.

6. The health worker vaccinates the children that are brought to her. The CareSquare works as a vaccination station, providing a table and easy access to all equipment. She will document all the children that get vaccinations either by fingerprint recognition or the traditional way with paper vaccination cards.

7. Malaria and diarrhea are very common in Nigeria, so when the health worker meets a mother whose baby has a disease she will give them medication. She will also answer questions of taking care of the baby the mothers might have and give education on nutrition, hygiene and immunization.
7 Project Planning and Management
6.1 Communication Strategy

Our communication strategy was divided into two halves: The first half was when the Aalto Team was in their native Finland or in Nigeria apart from the Stanford Team. The majority of this time, the Stanford team and the Aalto team were not together, therefore, the teams communicated utilizing remote communication services such as Google Hangout. The second half was when the Aalto Team traveled to California to join the Stanford Team on two separate occasions — during the middle of the Fall quarter and the last month of the Spring quarter.

Key elements in our communication strategy:

- Ensured constant communication between Stanford and Aalto teams.
- Ensured communication between the teams and our liaison, UNICEF. This included but it was not limited to: Mima Stojanovic our direct contact, Erica Kochi direct project management from UNICEF Innovation Unit, and Christopher Fabian direct project management from UNICEF Innovation Unit.
- Ensured communication with our teaching teams from both Stanford and Aalto Universities.
- Ensured communication with UNICEF Nigeria and all key elements from Nigeria involved in this project, such as Dr. Solomon Owumi.
- Ensured communication among other ME310 teams to exchange information and learn about manufacturing, materials, and any other crucial information that could benefit the project directly or indirectly.

Aalto and Stanford Teams at the same location:

Within the local teams the communication was mostly based on face-to-face meetings and working sessions. Additionally, email and Facebook chat was used to give updates on current progress. We used several methods to share our thoughts with one another. To create more ideas and build on them, we held brainstorming sessions (1-2 times per week). We had prototyping sessions that developed our ideas and led to our final prototype. We shared the results of individual works and built on those as a team. We held a debriefing of the results after interviews, observations and prototype testing to share what we learned and to build a common understanding.

Aalto and Stanford Teams at different locations:

To communicate when our teams were not at the same location, or to communicate with UNICEF, we used emails, Skype calls, Google+ Hangout, Facebook and chat.

Aalto and Stanford Communication with respective teaching teams:

Communication with teaching teams was anchored in the weekly SGM (small group meeting). There were weekly meetings in Aalto and Stanford where the respective teams shared the progress with the local teaching teams and received feedback and ideas. Progress was also shared via email. Communication Challenges
Communication Challenges

Our team faced great communication challenges during the entire project especially with our corporate partner. In the end our team members from Aalto University were not allowed to be in any direct contact with the UNICEF Innovation Unit, and therefore the Stanford part of the team had to act as the contact point for the project. Because of the lack of communication from our corporate sponsor and because our project was defined as an open-ended question, our team changed focus three times during the project. As soon as the communication improved with UNICEF and the project was less ambiguous, the team moved forward with the backpack project.

Another major communication challenge from both Stanford and Aalto's team was encountered when both teams traveled to Nigeria. While in Nigeria, the internet connection was not good enough to support Skype calls, sending pictures, video or even simple emails. We partially solved the communication problem during the trip by sending sporadic emails and having phone calls.
conversations. The negative side of this was that regular phone call conversations were expensive and most of the time the team members were not able to be present at the same time.

Despite the communication challenges, perhaps the most crucial moment in our project, came during our time in Nigeria. Trying to understand the root of the problem we were trying to solve, we performed user interviews, researched the overall community, and what we came up with was one staggering fact — healthcare workers were not visiting communities and worked strictly out of their healthcare centers. Even though, the official language in Nigeria is English, most of the members of the community, as well as the healthcare workers did not speak English but a local dialect. The language barrier created an invariable frustration when trying to understand the community’s needs, the major problems they were facing and how we could help solve them. We highly relied on a translator to get inside information from the community members and the healthcare workers.

**Learnings**

Because of the many communication challenges we adapted and learned a great deal about effective information sharing and decision making. Having a shared understanding of the overall communication process is essential. This means that every team member knows what kind of information needs to be shared and what is the right tool to deliver it. Being very explicit and prompt with emails helped us to share ideas and progress. This was especially true when communicating with UNICEF members because of their tight schedules.

We found it remarkably difficult to communicate our experiences in Nigeria. When presenting our findings we were forced to not only share our notes but all of our observations from our time in the country. We found that sometimes the most important information came from simple observations that we were able to communicate in our meetings.

In order to keep our updates between teams rapid and effective during our stints in Nigeria, we found the best way to share our progress was with daily summaries. These summaries included pictures and videos that demonstrated key insights from the field. This system required a significant amount of work when returning at night from the field.
6.2 Deliverables

Over the entire three quarters the team met different deadlines and deliverables. The table below shows, in sequential order, all of the assignments the team delivered.

<table>
<thead>
<tr>
<th>Date</th>
<th>Assignment</th>
<th>Deliverable</th>
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</thead>
<tbody>
<tr>
<td>January 17, 2013</td>
<td>Paper Robot Design</td>
<td>The team delivered two different robots. Both of them were able to communicate using 9600 protocol. Robots were able to send and receive inputs to establish communication with different robots.</td>
</tr>
<tr>
<td>January 31, 2013</td>
<td>Dark Horse Design</td>
<td>This assignment consisted of thinking outside the box. We delivered a fully functional prototype that explained extreme ideas and possibilities about how to transform the direction of our project. We delivered a 20-minute presentation and a brochure. The brochure included pictures, our predictions, unexpected findings, and how this project helped us to shape the direction of our overall project.</td>
</tr>
<tr>
<td>February 14, 2013</td>
<td>Funktional System Design</td>
<td>This assignment consisted of a fully functional prototype but we did not have to worry about statics. The prototype was able to construct, test and demonstrate how we are addressing child mortality in third world countries. For this project we conducted several expert in-</td>
</tr>
</tbody>
</table>
terviews to get feedback on our project. We delivered a 20 minute presentation and a brochure. The brochure included pictures, our predictions, findings, and how this project helped us to shape the direction of our overall project.

<table>
<thead>
<tr>
<th>Date</th>
<th>Assignment</th>
<th>Deliverable</th>
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</thead>
<tbody>
<tr>
<td>February 20, 2013</td>
<td>Aalto Travel to Nigeria</td>
<td>Half of our team, Aalto University, went to Lagos and Ibadan for two weeks in order to interact with users and gain insightful information about healthcare workers. During the trip they conducted several user interviews, got feedback from our current prototypes and interacted with the community at different levels.</td>
</tr>
<tr>
<td>March 7, 2013</td>
<td>Functional System</td>
<td>This assignment consisted on full functional prototype, from the inside (functionally, circuit, elements) to the outside (user friendly and ready to use). The main idea behind this prototype was to create something that someone could take home and use it. We did several user interviews in order to get realist information about who our user was and how our user felt about our product. We delivered a 20 minute presentation and a brochure. The brochure included pictures, our predictions, findings, the this project lead us to our final presentation and report to end of the quarter.</td>
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<td>Date</td>
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<tr>
<td>March 14, 2013</td>
<td>Winter Project Brochure</td>
<td>Two-page brochure providing a summary of the project goals and all findings to date. This final quarter brochure was distributed during the quarter final presentations.</td>
</tr>
<tr>
<td>March 15, 2013</td>
<td>Stanford Team travels to Nigeria</td>
<td>Half of our team, Stanford University, went to Lagos and Ibadan for two weeks in order to interact with users and gain insightful information about healthcare workers. During the trip they visited UNICEF main offices in Lagos, and they collected data from UNICEF about the community healthcare workers, their functions and responsibilities. Finally, Stanford Team relocated to the city of Ibadan for further user interface, benchmarking, and visit different healthcare centers.</td>
</tr>
<tr>
<td>March 17, 2013</td>
<td>Winter Design Documentation</td>
<td>Full documentation of all work done through March 2013. The document included all the information gathered in the winter quarter and should lay out a plan for work to be done through the Spring quarter in order to complete the project.</td>
</tr>
<tr>
<td>March 19, 2013</td>
<td>Winter Closure Checklist</td>
<td>Clean up all parts of work area; organize and file all receipts, paperwork and copies of previous deliverables; check status of budget and travel plans (Travel plans for Stanford team only from March 20 - March 31)</td>
</tr>
<tr>
<td>Date</td>
<td>Assignment</td>
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<tr>
<td>April 18, 2013</td>
<td>Part 'X' is Finished</td>
<td>Our Part X focuses on what we deemed the most critical portion of this system, the vaccination storage system. Our goal with this part is to create a storage system that is low-cost, lightweight, and compact, yet delivers enough doses to vaccinate an entire small community.</td>
</tr>
<tr>
<td>April 25, 2013</td>
<td>Manufacturing Plans</td>
<td>A detail list of all the materials and vendors we used in order to complete our product were listed in our manufacturing plans. We also included alternative materials in case our ideal material was not available, and difference in prices.</td>
</tr>
<tr>
<td>May 16, 2013</td>
<td>Penultimate</td>
<td>During penultimate a fully functional item needed to be deliver. However, since we defined our project at the beginning of the Spring quarter, our team was a week behind schedule. However, we were able to complete a full penultimate design by May 30.</td>
</tr>
<tr>
<td>May 28, 2013</td>
<td>Getting Ready for EXPE</td>
<td>General check up list, making sure that our brochure, posters, and booth were going to be done on time. Also, we need to send final reminders to our corporate partners, teaching coaches and anybody who contributed to this project.</td>
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<tr>
<td>Date</td>
<td>Assignment</td>
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<tr>
<td>May 30, 2013</td>
<td>Brochure Spring 2013</td>
<td>Two-page brochure providing a summary of the project goals and all findings to date. This final quarter brochure was distributed during the quarter final presentations.</td>
</tr>
<tr>
<td>June 2, 2013</td>
<td>Poster Spring 2013</td>
<td>A minimum one 3’ x 4’ poster was required, explaining our final product. Our team did two 3’ x 4’ posters, one with a real picture of our product and a second one explaining all the functionalities. Also, we did two small posters that conveyed our experience in Nigeria.</td>
</tr>
<tr>
<td>June 5, 2013</td>
<td>Booth</td>
<td>The booth’s theme was inspired by our trip to Nigeria. We were trying to create an environment similar to that in which the backpack is designed to function.</td>
</tr>
<tr>
<td>June 5, 2013</td>
<td>EXPE Presentation</td>
<td>We culminated nine months worth of work, in a 15 minute presentation. This presentation was two hours long where all the ME310 teams were able to present their work in front of an audience that consisted of teaching teams, corporate partners and other global members of the ME310 community.</td>
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<tr>
<td>Date</td>
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<tr>
<td>June 11, 2013</td>
<td>Final Documentation</td>
<td>Full documentation of all work done from Fall 2012, Winter 2013 and Spring 2013. The document included all the information gathered from the previous two quarters. Also, it has our complete deliverable to our corporate partner, explaining full functionality as well as room for improvement and future direction.</td>
</tr>
<tr>
<td>June 12, 2013</td>
<td>Final Checkout</td>
<td>Clean up all parts of the loft; turned in all the receipts for the end of the year reimbursement (paperwork and copies if necessary) review final budget and confirmed with teaching team that everything has been turned in and received.</td>
</tr>
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</table>
# 6.3 Project Timeline and Milestones

<table>
<thead>
<tr>
<th>Activity</th>
<th>Jan16</th>
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- **Specific date task was accomplished**
- **Actual date given to accomplish task**
7.4 Distributed team Management
Final Fall Documentation

- Gathering all the previous documents
- Schedule time to coordinate with Aalto - Stanford teams
- Fall Brochure
- Reviewing by TAs and all members
- Compile final document

Aalto Travel to Nigeria

- Leaving Finland
- User Interviews
- Testing prototypes
- Compile Information
- Return to Aalto

Stanford Travel to Nigeria

- Leaving California
- User Interviews
- Testing prototypes
- Compiling Information
- Return to California

Final Presentation

- Preparing material
- Assignment topics
- Rehearsing presentation
- TAs feedback

Paper Robot Design

- Planning
- Soldering and planning circuit
- Serial Testing
- Software Testing
- Final Implementation Robot

Dark Horse Design

- Benchmarking
- User Test
- Prototype
- Handout
- DarkHose Presentation

Funk-tional System Design

- Identify Subsystems Components
- Manufacturing Requirements
- Initial Testing
- Handout
- Presentation

Functional System

- Brainstorming
- Prototype
- Initial User Testing
- Building a second card and testing a different sensor
- Final User Testing
- Vision and Hangout
- Presentation

Aalto Team

- Noel
- Blake
- Janna
- Rohan

Stanford Team

- Hanna
- Juhana
- Inkeri
- Tushar

Paper Robot Design

- Planning
- Soldering and planning circuit
- Serial Testing
- Software Testing
- Final Implementation Robot

Dark Horse Design

- Benchmarking
- User Test
- Prototype
- Handout
- DarkHose Presentation

Funk-tional System Design

- Identify Subsystems Components
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Paper Robot Design

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- Soldering and planning circuit
- Serial Testing
- Software Testing
- Final Implementation Robot

Dark Horse Design

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- User Test
- Prototype
- Handout
- DarkHose Presentation

Funk-tional System Design

- Identify Subsystems Components
- Manufacturing Requirements
- Initial Testing
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- Noel
- Blake
- Janna
- Rohan

Stanford Team

- Hanna
- Juhana
- Inkeri
- Tushar

Paper Robot Design

- Planning
- Soldering and planning circuit
- Serial Testing
- Software Testing
- Final Implementation Robot

Dark Horse Design

- Benchmarking
- User Test
- Prototype
- Handout
- DarkHose Presentation

Funk-tional System Design

- Identify Subsystems Components
- Manufacturing Requirements
- Initial Testing
- Handout
- Presentation

Functional System

- Brainstorming
- Prototype
- Initial User Testing
- Building a second card and testing a different sensor
- Final User Testing
- Vision and Hangout
- Presentation
### 6.5 Project Budget

#### Stanford Budget

The Stanford half of the team was given a budget of $1000 for the fall quarter, $3000 for the winter quarter, and $4000 for the spring quarter to spend out of the prototyping budget. The following table shows all purchases made organized by date of purchase for the spring quarter. No rollover balance is shown from the previous quarters due to the fact the some travel cost overruns occurred, but the amount of the overrun was not immediately known, so this chart assumes no carryover. The actual balance at the end of the project is higher because the carryover balance is a positive amount, but this exact amount is not known to the team at this point.

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Rollover balance from Fall AY’13: $406.90

Winter Allocation: $3,486.50

Available Balance: $2,616.89
# Aalto Budget

## Nigeria travel costs
- Flight tickets: Helsinki - Lagos - Helsinki: 3176.35
- Visas: 595.95
- Vaccination and Medicine: 1588.17
- Hotel in Lagos, 1 night: 304.83
- Accommodation in Ibadan, 10 nights: 304.83
- Transport: Ibadan - Lagos - Ibadan: 178.33
- Field bus, gasoline, driver, 6 days: 416.86

**TOTAL travel costs**: 6565.31

## Prototyping costs

### Winter
- Baby doll: 30.48
- Cool box, 2 pcs: 26.67

**Total winter costs**: 57.16

### Spring
- Nigeria dresses x 4: 160
- Black folders for BabyBook: 37.90
- Stickers for BabyBook: 58.50
- Benchmark bag I: 39.00
- Benchmark bag II: 64.90
- Benchmark bag III: 95.00
- Content for the backpack: 132.49
- Backpack table materials: 56
- Miscellaneous: 14.47
- Sewing supplies Joann: 119.55
- Prototyping Home Depot: 304.89
- Maker faire ticket: 50
- Prototyping material other than Home Depot: 92.51
- Tailoring service: 525
- Posters: 394.33
- Communication: 60.86

**Total spring costs**: 2205.40

**TOTAL Prototyping**: 2262.56

## Total Budget
- Nigeria travel costs: 6565.31
- Prototyping: 2262.56

**TOTAL**: 8827.87
6.6 Process Reflection

Rohan Maheshwari

Despite some early apprehensions, this has turned out to be one of the most diverse and amazing projects that I’ve ever come across. During our trip to Nigeria at the end of previous quarter, we witnessed some stark revelations about the general status quo, which led us to a yet another drastic and inevitable change in the path of our project. This time it was about mobile vaccination drives, and restoring the lost faith of community members in the local health care system. Earlier, it was so hard to be empathetic, when all our sources were a second or third hand piece of information collected from interviews, documentaries, and journals, and to some extent imagination and logical reasoning. But, after our expedition, my perception towards a seemingly mundane routine of our persona, seemed so non-trivial and unsettling. Back home in India, I was actively involved with lots of NGOs(Non Govt. Organizations) doing related work in the vicinity, but there is a huge disparity when one is dealing with small african villages, as situations are a lot worse there as compared to slums in a metro. It’s weird how a considerable proportion of our global population is still devoid of basic necessities of life, when for others it’s almost equivalent to a granted right. The harsh reality is that most of us just don’t do anything about it, not because of the callous attitude but because of sheer unawareness.

Shifting our focus at such a later stage of product development also meant that we had to essentially complete the entire ME310 in a short span of 9 weeks. When one is working with this amazing group of people from different parts of the world, effective communication, and getting your point across is always challenging. I’m not sure if it was the impending deadlines, but I personally felt that for the first time our group of eight students was actually working as a team. Saving lives is perhaps the biggest gift that one can give to humanity, and by focusing on children, we are not just saving a single generation, but also ensuring so many future possibilities, that otherwise wouldn’t have even existed.

Tushar Malhotra

“It is an unequal world. So much in an individual’s life, even access to the basic human needs like food, shelter and clothing, depends on a random event - that of being born in a particular part of the world. I see this project as an opportunity, perhaps not to make a difference yet, perhaps not to contribute anything substantial at this point, but at least to try and to begin to understand the realities of the world we live in but are oblivious to, most of the times.”
- From my reflection during fall quarter

After the trip to Nigeria, the above quote from my reflection seemed like a self-fulfilling prophecy. The trip was exhausting, uncomfortable, overwhelming and even frustrating at times but definitely enriching. Besides being extremely fruitful from the perspective of the project - we were able to do a lot of work in the field and learn a great deal about the context first-hand - the trip was also an enlightening personal experience and a chance to see life in a different culture and in a context where, due to socio-economic circumstances, not everything works and the basic assumptions we make about our everyday lives are not necessarily valid.
This final quarter was interesting from two perspectives - one, this was the first time when we, the two partner teams, started converging to a single solution. While this process of converging was somewhat aided by the teams’ relatively similar experiences in Nigeria, there were nevertheless some differences of opinion. Fortunately, the second aspect - the fact that we traveled to Stanford in May and started working together in person, helped a lot in communication and thus in discussing and ironing out the differences as and when they arose - face to face communication trumps any amount of virtual face time and our experience only reaffirmed the same!

Overall, this year and the project have been unlike most other I have worked on. While the journey has been challenging and even frustrating at times, it has been immensely rewarding and enriching at both personal as well as professional levels.

**Inkeri Niinimäki**

When I look back myself before this course compared to now, the first thing that comes to mind how very naïve I was back then. First of all my image of Africa was more than a little romanticized, but I think no one could truly even begin to understand the conditions of living in a country like Nigeria before going there and experiencing it. I have also learned in this course what kind work organizations like Unicef in reality do. But I was naïve also about the process too and underestimated the problems: When the TA’s were telling us about the communication problems I remember thinking, but our global team speaks English as a mother tongue, how could we have any communication problems? Now I have learned that even the language is not the problem, there can still be very different communication cultures. And even though I found it hard to believe in the beginning, building prototypes really does take always more time than one would think.

The best part of this course for me was to work in a multidisciplinary and global team. I think I learned most in this course from teammates. It has been wonderful to meet all the amazing and talented people in this course. The culture in this course has been very unique and it has been great to be part of it. Also Design Factory as working place has been wonderful – The freedom to use the facilities any time of the day and to always have someone there to help you.

I feel that I have learned a lot even though definitely not the easy way. I hope our project can serve as a learning experience also for the future development of the whole course. First of all since one of the basic principles of design thinking is understanding the user and their context, there should be opportunity for the team to meet users much earlier than what was the case in our project (in the end of February/March and Spring break). Before the travel we could only prototype solutions for problems found by others and that are so common knowledge that the solution spaces were already saturated. Also it was less motivating and felt artificial to come up and test solutions in the most developed countries in the world without any firsthand experience of the real context in the developing world.

Working in this project also showed the importance of meeting with the global team in face to face also during the year, hopefully all the teams get to do that in the future. In addition to going to the field far too late, not meeting face-to-face affected us not to be able to make the decision of the final direction until late into the last quarter. Even after the Aalto part of team travelled to Stanford to work together, since both of global teams had been working in very different ways, it took time to adjust to the other way of doing. But still the last weeks working together were the most efficient and productive ones and we came a long way in very short time. Also I think meeting during the year would be not only fun but important also as a bonding experience for the team.
Finally, in the future I think a startup, like the ones that we have come across during this project, dealing similar problems than our project, but with a little more refined scope and similar working cycles than this course, would be a better match for this course than a big hierarchical organization.

**Juhana Nurmio**

The past nine months have definitely been a unique learning experience. Multi-disciplinary teamwork, global communication, 3rd world exposure, design thinking process, rapid prototyping, electronics, mechatronics and finishing a product were among my favorite takeaways from the course. And of course dancing with ambiguity, I think our team got a special chunk of this one!

The project was extremely difficult and I still feel that our team never performed in a state where we would have been excited and enthusiastic about our work. The whole year felt more or less like hitting head against the wall. The troublesome relations with Unicef definitely impacted our team’s morale and we actually never truly recovered. The visit to Nigeria came far too late and the fact that Stanford students travelled two weeks after us made it even worse. Once we finally came up with our final concept it was very late and the scope we were able to deliver was not satisfactory for us. However, taking into account the short time we had, I am proud that we were able to deliver a relatively finished product.

I enjoyed greatly the atmosphere and culture of ME310 in Aalto University. It’s so much more than a course. It is a community for life. I feel awesome to be part of it! I was amazed how well Aalto handles the competition with Stanford or any other university involved. The level is outstanding and definitely on the very top of the world. I wish we could do a bit better job in marketing and spreading the knowledge both in and outside Aalto. ME310 has a unique position to truly impact the teaching and learning culture in Aalto University.

**Hanna Poranen**

The journey from the starting point of the course to the final EXPE with ready prototype has not been easy or clear. I still think we got out very well and managed to make a product that could actually have an impact in the developing world. Especially the final four weeks of the course our team worked hard to get everything done and I’m very happy that I had an opportunity to be part of that process and learn from my teammates.

Important turning point for me in the project was our field trip to Nigeria. The whole process and work we did got finally real context there and gave so much more value for our effort. The importance of meeting the real users can’t be underestimated. I truly wish that we could have had a change to go to the field much earlier and so on start the final product development much sooner. Even though ambiguity is highly appreciated in ME310 world, I would say that somewhat preplanning helps to achieve more. The field trip was also affected by the communication with our corporate liaison. In terms of communication this course has tough me a lot. Especially the collaboration of global teams has been a good experience. To communicate between three continents, Europe, Africa and North America, has been challenging, but at the same time interesting. I have found new things from my self and others.
The Nigeria trip was for sure a lifetime experience, eye-opening and shaking. Before ME310 I had just mover back to one of the world top welfare countries, Finland, from China, where I had been living over 1.5 years. Still that or my scouting background couldn’t totally prepare me for Nigeria. Low living standards and lifestyle was something I had never seen and made me think the way we live here and the value of our project. I would like to thank ME310 for these experiences and giving me this opportunity.

**Blake Reece**

For the first 5-6 months of this project, our team was continually starting over, and it seemed impossible that we would ever be able to fully understand our problem space, yet alone create a solution within it. We could not test, we could not gather accurate data, and most importantly, we could not meet and begin to empathize with our potential users. We were, quite frankly, a bit lost.

This all changed when we were able to travel to Nigeria and witness the health breakdowns firsthand. Even with descriptions from the Aalto students who had just been to Nigeria, there was just no way to fully comprehend our project until visiting the country and speaking to users. The trip re-energized us, and we developed a fully functional product in less than 10 weeks; a product that we feel could truly help the relationship between the health system and the people it is intended to serve.

This trip was truly a once in a lifetime opportunity for me, and I am so thankful to have had the opportunity to go. Problems that don’t seem too complicated from the comfy confines of Stanford are made much more real when you personally experience them for yourself. It is one thing to go through a little rough spot in life, but it is a completely different thing to be completely surrounded by a society and culture that leaves individuals consistently fending for themselves. It is a world with no trust, no empowerment, and often no hope for things to improve. Contrary to what I believed coming into this course, there are no quick solutions or fixes that can magically erase the problems seen in developing worlds. However, I do feel that if a product like the CareSquare can empower even small numbers of people, Nigeria and countries like it will move in an upward trajectory. The key is, people have to feel like they are not in a fight all on their own; they have to feel as if they are part of a movement that actually leads somewhere, instead of quick fixes that simply lead to more of the same old problems.

I am very proud of what we developed, and even if it does not survive as the same product moving forward, I hope it provides some sense of empowerment for the Nigerian people. The idea behind CareSquare is that healthcare workers and communities can take charge of their future, and I truly believe that people can feel empowered in developing nations, great things will occur.

**Janna Rodriguez**

Nine months ago we were charged with an ambiguous and daunting task — to solve one of the five major world killers of children under the age of 5. UNICEF, our corporate liaison in this three-quarter long project, delivered this directive to us. Facing a problem that has so many potential angles, it took us from sanitation to diagnosing pneumonia to closing the gap between healthcare workers and community members. No matter the lens we looked through, the solution was never simple, and it seemed that many had tried and failed at tackling these enormous issues before us.
During my ME310 journey, I learned needfinding, benchmarking, and quick prototyping techniques, but I also learned about empathy. It was empathy, that helped me understand different perspectives from my team members and that helped us to move away from frustration when we could not get answers from our corporate liaison. And while in Nigeria it was empathy that helped us to understand that lack of leadership, corruption and lack of self-motivation were potential sources of the problem that we could affect.

We went to Nigeria to test a pneumonia-diagnosing device with the idea that a device was going to majorly reduce mortality in one of the major killers of children under the age of 5. As soon as we stepped into the first healthcenter, we discovered pneumonia detection was not the problem and that the healthcare workers were capable of properly diagnosing pneumonia with their current skills and tools. We were forced back to the drawing board and to completely rethink our approach to tackling this enormous task. We spent two weeks in the field and we soon discovered that healthcare workers lacked self-motivation. We saw obvious gaps between them and the communities they should have been serving. We reframed our problem statement to something more concrete such as, “how can we bring the healthcare workers and the community together?”

We knew that there were two possible ways to solve this problem. The first was by creating a campaign that could motive an entire community to visit the healthcare center. This solution was not feasible, since the community had lost their trust in the healthcare system, they lived too far away, or they just didn’t see the benefit of going to a healthcare center. Our second solution was to bring the healthcare workers into the communities.

The healthcare workers were not motivated enough. We determined through interviews and research that a major factor in their inability to deliver services to the communities in need was the lack of mobility with their tools and equipment. Our solution was a backpack called CareSquare — a clinic in a backpack. Our intention was to create a product that the healthcare workers were proud of carrying and therefore more likely to use. The backpack was designed to be a rugged and attractive pack that could house all the tools and sanitation equipment a healthcare worker would need to provide a mobile vaccination drive or basic health care.

Nine months ago, I would never have imagined that what we were going to design a backpack, today, I am sure that our product will severely reduce the children’s mortality rate in Nigeria and will also close the communication gap that is preventing the healthcare workers from reaching the communities that are desperately in need of their services. Our problem was never defined as “make a backpack.” We empathized with the Nigerian people, we made a connection, we understood the problem and we proposed a feasible solution based on the skills we learned throughout the year.

Noel Spurgeon

After traveling to Nigeria, my perspective on the problem that we were trying to solve was completely changed. Were I to do the course over again, I would have traveled much earlier: actually seeing the situation in context was an invaluable experience, and I would have liked to have more time to mull it over before coming up with an actual design. In addition, I would have liked to make a second visit, so that we could do more targeted interviews. The first visit was largely fact-finding, which was valuable, but not particularly targeted.
In terms of the actual situation in the field, the thing that surprised me most was how big the problem was. Tackling a disease at a specific point with an antibiotic or rehydration is one thing, and it seems extremely manageable on paper. However, the situation is far more complicated than that in reality. The link between the healthcare system and the people that it’s supposed to serve is profoundly broken, partly because of logistics, and partly because of the lack of a good relationship between the clinic and communities. This caused us a lot of grief when we came back, because the problem seemed insurmountable. We were used to thinking of problems from the comfort of Stanford, and faced with the reality of the situation, we weren’t sure about anything any more. That’s what makes Nigeria such a frustrating context. Although the country is saturated with oil, boasts fertile soil and a prime location for shipping and commerce, mismanagement has caused widespread poverty and chaos. People are unempowered and disenfranchised, and worse, most are resigned to the status quo. Trying to fix even a fraction of the problems that we saw there would be a daunting task.

I think the most important lesson that I learned from this is that having the perfect solution isn’t necessarily possible, but having a good solution that addresses multiple issues is usually more than enough. Problems of this scale are solved by a combination of several smaller solutions working in concert, and you’ll drive yourself mad if you burden yourself with trying to execute a flawless plan. It is nearly impossible to fix every problem that you come across, but if you can impact the lives of a few people and empower them, they may be inspired to do the same for others.
6 Resources
7.1 Bibliography

References chapters 2.1:


3.2.1


4.6.1:


4.7.0:

nigeria-national-vaccine-summit-town-hall-report.pdf

4.7.1:


References chapter 5.4. same than 3.2.1:

8.2 Human Resources

Andrew Clutterbuck
Organization: Coach / Community Manager at Aalto Global Impact
Work History: Andy has been involved with building the AGI - UNICEF partnership especially in context of the work being done in Uganda and has been mentoring students during their projects.

Bhavna Hariharan
Organization: Research Program Manager, KGC, Social Science Research Associate, School of Humanities and Sciences, Stanford University
Work History: She has been working in western parts of India, especially rural areas around Ahmedabad in Gujarat, to eliminate open defecation.

Hannele Virtanen
Organization: Red Cross, Finland
Work history: 20 years in the field all over the world. Senior Health Advisor with Red Cross

Heikki Marttila
Organization: IDBM Student
Work history: IDBM project in Uganda. The goal was to observe and evaluate existing solution developed by previous student teams and give suggestions to scale the ones that are working or find ways to make them work.

Irena Bakic
Organization: Aalto-UNICEF collaboration project coordinator at UNICEF, Finland
Work History: Irena has been involved with the Aalto-UNICEF partnership in various roles over the past two years. She has also worked as the project manager for the PDP project in Uganda.

Marianne Prasad
Organization: University of Helsinki, Finland
Work History: Researcher at the University of Helsinki, involved with the GloCal project focussing on delivering mobile healthcare solution related to nutrition in India
Otaniemi Kindergarten,
Children age group 3-6,
Servin Maijan tie 8,
02150 Espoo
FIN

Saara Nokelainen
Organization: World Vision Finland
Work history: World Vision, Finland, Uganda Program Coordinator. Has been working in the field in India, Uganda and Kenya

Sari Huuhtanen
Organization: Käymäläyhdistys Huussi Ry
Work history: Project manager. Done sanitation projects in Zambia

Sujil Kodathoor
Organization: Aalto Global Impact, Finland
Work history: Creative Sustainability Master student at Aalto, Worked on the Glocal mobile healthcare project in India addressing malnutrition. Extensive field work in various settings - Rural, Tribal, Slums etc.

Solomon Owumi
Organization: Postdoctoral Research Fellow, Genetics, School of Medicine, Stanford University
Work history: Researcher in Ibadan University, researcher in Stanford University

Teija Lehtonen
Organization: Aalto Global Impact, BOP research group
Work history: Director of Aalto Global Impact. 3 years in India, 3 Sri Lanka, 2 Africa (West Africa), 2 Denmark. Red Cross e.g. field hospitals.

Kirsi Peltola
Organization: Pelastakaa Lapset - Save the Children
Work history: 5 years in Africa, Mostly in Kenya e.g. in WASH hygiene project as an instructor
Andy Chang
Organization: School of Medicine, Stanford University
Work history: His previous experience includes developing a Hepatitis B screening and health maintenance program at Pacific Free Clinic in San Jose, interning at Nyaya Health, a health initiative focused on building a primary care and maternal health center in rural Nepal.

Peter Mulligan
Organization: Stanford University
Work history: His research interests lay at the intersection of engineering and biology. He has interned at Laureate Pharma and in a medical genetics lab at the University of Pennsylvania and has worked on microfluidic chips that can do PCR. He studies heterochromatin and DNA packaging through computer simulations. Through his coursework, he has learned about desalination, water purification, microfluidics, global health challenges including tuberculosis, and environmental biotechnology.

Sebastian Tilmans
Organization: PhD candidate, Environmental Engineering & Science program
Work history: He has spent 3 years in Panama designing and building energy-producing sanitation systems in rural communities. His passion is to transform society’s waste streams from liabilities into tools for social, environmental, and economic good. He was a Fulbright scholar and an NDSEG fellow, and now studies under an EPA STAR fellowship. When he’s not sticking his head in toilets, you can find him basking in the nearest body of (clean) water with a big smile and insufficient sunscreen.

Mark Thomas
Organization: VaxTrack
Work history: Executive Director of VaxTrack

Oladimeji Oladepo
Organization: University of Ibadan
Work history: The head of department of Health promotion

John Imaledo
Organization: University of Ibadan
8 Appendices
8.1 Expert Interviews

CURRENT SANITATION IN INDIA

Name: Bhavna Hariharan
bhavnah@stanford.edu
Stanford University

Background: Research Program Manager, KGC, Social Science Research Associate, School of Humanities and Sciences, Stanford University
Work history: She has been working in western parts of India, especially rural areas around Ahmedabad in Gujarat, to eliminate open defecation.

THE GENERAL IDEA

Bhavna has been working in sanitation and hygiene in India for over five years. She has been researching problems that tackle water, infrastructure and sustainability.

Her focus had been on engineering education
How to inform people about sanitation.
Research about toilets been only part of the solution, and the taboos behind building toilets.
Waste management issues in India.

Incorporate the current solutions that are in the market to try to solve the problems.
Research new technology such as Bio-Plastic with the goal of finding cheaper and more sustainable ways to fix sanitation problems.

Design in conjunction with the community. For instance, they designed a self-cleaning toilet in collaboration with the members of the community.
They explored solutions such as the diarrhea vaccine and programs that encourage people to constantly wash their hands.

Rate of creation is far greater than rate of decomposition.

More information:
http://kgc.stanford.edu/people.html
EXPERIENCES FROM FIELD WORK IN UGANDA

Name: Saara Nokelainen  
World Vision Finland

Background: Suomen World Visionin Ugandan ohjelmakoordinaattori. Työskennellyt kentällä Ugandassa, Keniassa ja Intiassa

THE GENERAL IDEA

When pregnant women are in labor, they have to bring their own supplies Sheets, Safety pins, Bandages

Basic toilet Cement floor, Might be porcelain in cities, Big container, when fills up build new one, Weak ceilings, Rains and ceilings might bring up the shit

Hand wash a small initiative by Community Health Workers, Volunteers, farmers, often women, 2 per village, Go home to home, From afternoon, it's dark around 1830hrs, Bring medicine, soap, Educate, Medicate about 10 people, Walking, bicycling, Organized by government

Health centers lack laboratory equipment 4-5 minutes per patient, Not much things, HIV test, basic things like scale, Shortage of medicines, Storage

Problems Malaria, Bad air quality from smoke making food inside, Respiratory organ illnesses, Western designs don’t work from cultural reasons, eg. in habit of boiling food sitting down, standing up ovens don’t work, No electricity in the rural area, Keeping the water (säilytys), Breastfeeding, some don’t use the first best milk, Important what the mothers eat during pregnancies, Slums

Children’s duties Getting water eg. 5 l jerry-kannu, Boys: herding, Getting wood, Making food

More information:  
http://www.guardian.co.uk/katine/2009/apr/01/uganda-healthcare-system-explained
INCLUSIVE INNOVATION PROJECT

Name: Teija Lehtonen
Aalto Global Impact, BOP research group

Background: Work history: Director of Aalto Global Impact. 3 years in India, 3 in Sri Lanka, 2 in Africa (West Africa), 2 in Denmark. Red Cross e.g. field hospitals.

THE GENERAL IDEA

Problem if the brief too wide
Too much time spent in general information
Doesn’t help anyone, Eg. Mobile Diagnostics project in India

Key Select Good partners
UNICEF might not be enough, might need local (NGO) partners too
New country with new contacts takes too much time

Limited time in the field Plan all the meetings beforehand
Good team spirit is important
Try to have a Finnish company as a partner to bring the project forward
Mobile
Not only text anymore, but video and pictures
Ideas
things to check

Suggested countries with already existing Networks
Tanzania, Uganda, Mozambique, Kenya, Zambia

Suggested partners
Save the Children, Red Cross, World Vision, Ministry of foreign affairs, University of Helsinki
TEKES (Auli Pere), Medix Biochemica (Diagnostics in India)

More information:
http://www.aaltoglobalimpact.org/
PROBLEMS, CHALLENGES, AND GENERAL EXPERIENCES IN NIGERIA

Name: Andy Chang
ychang@stanford.edu
School of Medicine, Stanford University

Background: His previous experience includes developing a Hepatitis B screening and health maintenance program at Pacific Free Clinic in San Jose, interning at Nyaya Health, a health initiative focused on building a primary care and maternal health center in rural Nepal.

THE GENERAL IDEA

Big question
Address pediatric respiratory distress

Pure oxygen not really recommended
Can cause inflammation in lungs
Expensive
Heavy cylinders make it harder to carry

Cost-effective
It should be cost-effective
Kits might be more user-oriented

Recommendations
Talk to doctors, patients, and mothers in the target areas
Making it powered, might restrict it to specific locations
Few moving parts

More information:
http://extreme.stanford.edu/projects/inspire
IN-HOME TOILET DESIGN FOR HAITI

Name: Sebastien Tilmans
pjm2008@stanford.edu
Stanford University

Background:
PhD candidate, Environmental Engineering & Science program Year: First-year
Topics of Interest: Sanitation, resource recovery from waste, water quality

THE GENERAL IDEA

• Separation of waste
• Use chemical product that will create a chain reaction that will process the defecated waste and converted into fertilizer in a matter of hours.
• Contained the urine in sealed containers that prevented air contamination.
• His toilet uses water, since water is not a problem in Cambodia.
• The waste is currently disposed in two-meter-deep underground latrines that are emptied every two years in a very unsanitary way.
• After the latrines are cleaned, they are still unsure what people do with some of the waste.

More information:
http://h2o.stanford.edu/research/integrated-mobile-sanitation-solutions-peri-urban-settings-haiti
SANITATION PROGRAMS IN ZAMBIA, OUTHOUSE TOILET DRY TOILETS

Name: Sari Huuhtanen
Organization: Käymäläyhdistys Huussi Ry
Work history:

Background: Project manager. Worked on sanitation projects in Zambia

THE GENERAL IDEA

Culture forms technology, not the other way around”
Still a lot of projects/products that people won’t use

Dry toilets
urine separated
fertilizer from feces
not good for children/old/disabled, because of stairs

Pilot cheaper toilets failed
People didn’t like bamboo ceilings, because they broke after rains
ants ate bamboo chimneys (usually done from PVC plastic)

Ownership
Never for free, or people don’t care
3 levels of support, first level pay all, but even last level has to pay e.g. by making tiles

Continuity
Sanitation clubs
Creating entrepreneurship
tile making
collecting
PROBLEMS, CHALLENGES, AND GENERAL EXPERIENCES IN NIGERIA

Name: Solomon Owumi
seowumi@stanford.edu
Postdoctoral Research Fellow, Genetics

Background: Organization: Postdoctoral Research Fellow, Genetics, School of Medicine, Stanford University
Work history: Social activist in Northern Nigeria

THE GENERAL IDEA

Most prevalent
Malaria in urban and rural areas
Cheap and ineffective Chinese drugs

Pregnancy complications
Teenage abortions by quacks, disparity of ages in marriages, weak pelvis, ‘vesico vagina fistula’ complication

Corruption
Endemic, dreaded capitalist economy, large proportion of assets owned by very few people

University of Ibadan
The university, especially med-center, is doing some really awesome work, and we might collaborate with them

Cellular network
One of the greatest cellular network penetration factors among the third world nations
Power for smartphones an issue

Toilets
Septic tanks, weekly suction trucks

Water
Enough (clean) rivers
Ongoing rain-water harvesting efforts
Almost no drought-concerns, au-contraire, it witnessed a deluge recently

More information:
http://med.stanford.edu/profiles/Solomon_Owumi/
GETTING INFORMATION AND INSIGHTS ABOUT AND HEARING EXPERIENCES OF HER (AND RED CROSS’S) WORK IN DEVELOPING COUNTRIES

Key Insights

Explore the solar water treatment space - research already done etc.

Explore waste-management related solutions

Name: Hannele Virtanen
Hannele.Virtanen@punainenristi.fi
Red Cross, Finland

Background: Work history: 20 years in the field all over the world. Senior Health Advisor with Red Cross

THE GENERAL IDEA

Sanitation and waste management is indeed a big concern in refugee camps and in the developing regions in general.

Changing behavior / culture and communicating well is the key, by far!

E.g. Preference for water based toilets - even though they prove to be less clean, harder to maintain and use (because of lack of water e.g.) - very hard to convince people to use non-water based toilets. However, once a few people were convinced, they proved to be better advocates within the communities.

Bigger hospitals are generally well equipped - may not be a lot of opportunity there. Perhaps the biggest problem is for securing power supply - gensets, batteries etc.

Mobile technology based innovations are spreading fast and a lot of work has already been done. Local people are smart and work out solutions (even if they are workarounds) on their own for most problems.
UGANDA IS FRIENDLY, WARM IN SPIRIT AND ASCETIC. THE VISIT WAS INSIGHTFUL AND EMOTIONAL ROLLERCOASTER …
- HEIKKI

Key Insights

Get experiences from student group (IDBM) field visit to Uganda. 10 days in Gulu (rural town, and the second biggest city in Uganda) and 4 days in Kampala (the capital city)

Soap: school kids are able to produce soap from NaOH and food oil

Name: Heikki Marttila
heikki.marttila@aalto.fi
IDBM

Background:
Forestry engineering (Aalto CHEM)
Project: IDBM project in Uganda. The goal is to observe and evaluate existing solutions developed by previous student teams and give suggestions how to scale the ones that are working and/or find ways to make them work
Clean school concept, Elephant water, Water carrying system for kids (10-20 litres)
The project started in September and is due in May

THE GENERAL IDEA

Do the visit as early as possible to get the proper mind set

People in the rural area (near and in town Gulu) are very poor. Live with a daily income of 1-2 dollars. Kampala is the capital and there people have more wealth but there are also slums

Critical observation of the locals and living conditions: people tend to fake and say it’s better than it actually is. For e.g., district officials say they do regular control visits but in reality they can’t afford to gasoline to drive to schools (1 dollar / litre). Also, schools put the soaps into the toilets just before the observers showed up.

Interviews vs. ask people to show / do and observe. Group interviews vs. individual

Church has an important role. Over 80 % are Christians (13 % Muslims). Church might have big influence on people’s behaviour and be part of the solution / problem.
EXPERIENCES FROM FIELD FROM A HYGIENE PROJECT IN KENYA

Name: Kirsi Peltola
Pelastakaa Lapset ry
Save the Children

Background: 5 years in Africa, Mostly in Kenya e.g. in WASH hygiene project as an instructor

THE GENERAL IDEA
When lecturing about hygiene, Child, “how can bacteria be dangerous if you can’t see them?”
Ownership Co-creating with children, school make songs or make them make statistics
If the school feels it’s “their thing” they will continue it decide for themselves where to place all the toilets
Ethiopia is different from other African countries you can’t question their traditions at all
Children can teach to other children (e.g. younger siblings) but not that much to adults
Education for mothers Aunts teach, “we have always done it like this”.
Breastfeeding no time, work far away, maternity leave max. is 4 months. Usually less, e.g. 2 months
Wanna treat the children with something “better”, soda, cookies. Wrong information.
No trust to government People live with 1 euro day, Might save up 20-30 euros for small business
Africa is more expensive than Asia, Food price fluctuates a lot (partly government “cheating”)
Important purchases in life Mobile phone (70% has mobile phone in Kenya.), pirate 5-10 euros
real same price than in Finland, Private school (don’t trust the public schools), car, Own land very appreciated
Family planning Having lots of children, so that if 6 of them “go bad”, the mothers still have a few to
take care of them when they get old
About culture People are relaxed, but timetables aren’t kept, Don’t worry about the future
Everything is based on social relationships, work comes after that, Christianity is very prevalent
Education isn’t related to real life, but still very appreciated. They don’t learn to question old things
or to have own ideas. Learn about american history, but not what is the nearest city
Not a reading culture, documentation very reluctant, It gets dark by 7; don’t go alone (or with 2, or 3)
Father is the head of the house, relatives come and go. Families changing, when moving to city
people lose ties, grandchildren may not learn grandparents language
Tips Girls don’t wear shorts, people will think are “slutty” and might rape
Salt sugar for diarrhea.

More information:
http://ezpzextreme.wordpress.com/
MAKING SANITATION PAY FOR SUBSISTENCE FARMERS

Name: Peter Mulligan
pjm2008@stanford.edu
Stanford University

Background: Peter Mulligan received his B.S. degrees in Chemical Engineering and Biology at MIT in 2008. Currently, he is pursuing his Ph.D. in Chemical Engineering at Stanford under Andy Spakowitz. His research interests lay at the intersection of engineering and biology. He has interned at Laureate Pharma and in a medical genetics lab at the University of Pennsylvania and has worked on microfluidic chips that can do PCR. Currently, he studies heterochromatin and DNA packaging through computer simulations. Through his coursework, he has learned about desalination, water purification, microfluidics, global health challenges including tuberculosis, and environmental biotechnology.

Key Insights
• While he was taking a class at the D.School at Stanford called “Design for extreme affordability”, him and his team were assigned a project to design toilets for a Cambodian Community.
• Their goal was to transform waste into a farming fertilizer; their main focuses were in the following areas: Create something economical and sustainable
• Attractive to the farmers

THE GENERAL IDEA
• Separation of waste
• Use chemical product that will create a chain reaction that will process the defecated waste and converted into fertilizer in a matter of hours.
• Contained the urine in sealed containers that prevented air contamination.
• His toilet uses water, since water is not a problem in Cambodia.
• The waste is currently disposed in two-meter-deep underground latrines that are emptied every two years in a very unsanitary way.
• After the latrines are cleaned, they are still unsure what people do with some of the waste.

Figure X:
Su Sann’s latrine with the EZ*PZ

More information:
http://ez
Title: General Procedure to Detect Pneumonia at Stanford Hospitals

Date: January 30, 2013
Name: Dr. Ware Kuschner, M.D.
Professor - Med Center Line, Medicine - Pulmonary & Critical Care Medicine
kuschner@stanford.edu

Background:
Fellowship: University of California, San Francisco, Pulmonary and Critical Care Medicine (1996)
Residency: Columbia-Presbyterian Medical Center, Internal Medicine (1992)
B.A.: Middlebury College, English (1985)

My principal research interest is in occupational and environmental lung disease. I am interested in the health effects of airborne toxicants in exposed workers and the health effects of outdoor and indoor air pollution. My work includes experimental human research studying the acute effects of toxic inhalational exposures. I also conduct observational analyses assessing exposure-effects relationships in selected populations. I have a secondary area of academic interest in medical ethics.

The General Idea:
Definition: pneumonia is an infection on the lungs.

How the lungs work: Bronchial breathing tubes are conductors or pathways, which air (oxygen and carbon) comes into the lungs and distributes into the lung tissue, and the airways are one compartment in the lungs. Then, the oxygen is been delivered into the bloodstream and carbon is been delivered back to the environment.
The airways are very sensitive to a variety of infections. Anything that involve the airways it is call the “branchroidas”. Pneumonia affects the airways and the lung tissues where gas exchange occurs.

Common misdiagnosis of pneumonia:
Cough (bronchitis) it could be infections or not infections, virus, fungus bronchitis.
Inflammation or inflation of the breathing tubes.

Symptoms of pneumonia:
Pneumonia is a serious condition where the lung tissue is extensively infected with some soft of microbiological agent, bacteria, and possibly a virus, tuberculosis or a fungus.
Features of pneumonia:

**Acutely:** in hours

**Semi-acute:** weeks, maybe years

**Symptoms:** Cough, mucous, wet cough, fever, shakess and chills, feel short of breath (more with walking) or at rest, and the shadow in some x-rays (demonstration of a shadow or multiple shadows, opacity). A classic bacteria pneumonia will develop in matter of days.

Current way to diagnose pneumonia:

Steps 1: An X-ray shows a shadow in the lung system and other laboratory data supports or is consistent with pneumonia:

Step 2: A measurement of the white blood cells, which will be elevated.

Step 3: the measurement of oxygen in the lungs, the oxygen level will be reduced in patients suffering from pneumonia.

Step 4: Blood and Urine test for specific types of bacteria, specific types proteins will release to the blood or sometimes the urine that will revel pneumonia.

**Treatment:** Some patients can be treated with antibiotics, others have to come to hospital and others have to go to intensive care unit.

Why people get pneumonia?

It is not totally clear and it is uncommon for healthy individuals. But the following people are most likely to contract pneumonia:

- Smokers
- Drinkers
- Drug users
- People with cardiac problems
- HIV patients
- People suffering from cancer and going through chemotherapy
- Organ transplant patients
- Newborn
- Elderly

People develop pneumonia and others don’t:

Our mouth is full of bacteria, but our body fights that bacteria even when we are asleep, our immune system protects us.

Chronic respiratory infection:

Tuberculosis (TB) (developed in 1940s) is easily transmitted, and about 15% of the people in the world are infected it doesn’t mean that they have the disease, but the immune system of these people fight it back and there are fine, but about 10% of people will develop TB.

**Symptoms of tuberculosis**

- Loss of appetite
- Fever
- Weight Loss

and it is difficult to diagnose.
Other types of pneumonia:
- come from fungus

General questions asked to a patient to diagnose pneumonia:
Physical Examination (History):
What is the problem?
Do you have cough?
Do you have paint?
Do you having a fever?
Are you having chills?
Do you still have energy?
What does your mucus look like?
Listening to lungs? (if the lungs are filled with water, it will have a dole sound)

Empirical therapy: Doctors treat with antibiotics.

Similar symptoms to pneumonia related to the respiratory: bronchitis, emphysema, heart problems, asthma,

More information:
http://med.stanford.edu/profiles/Ware_Kuschner/
Title: Pneumonia in Children

Date: Tuesday February 5 at 1pm
Location: Stanford Medical School
Name: Nanci Yuan, MD
Clinical Associate Professor, Pediatrics - Pulmonary Medicine
nyuan@stanford.edu

Background:
Clinical Focus: Pediatric Pulmonary, Pulmonary Medicine/Cystic Fibrosis, and Pediatric Sleep Medicine: Professional Education
Board Certification: Sleep Medicine, American Board of Pediatrics (2009)
Board Certification: Sleep Medicine, American Board of Pediatrics (2009)
Board Certification: Sleep Medicine, American Board of Sleep Medicine (2005)
Board Certification: General Pediatrics, American Board of Pediatrics (1999)
Fellowship: Children's Hospital of Los Angeles CA (2003)
The General Idea:
She recommended looking at the WHO general clinical guidelines since pneumonia symptoms might be different depending on the region.

The Urine test:
It is not recommended since it will only work for one particular bacteria. Pneumonia can't be detected the same way that we do it with malaria. We can't use one single test that will display a positive or a negative result.
Pneumonia to her is an infection on the lungs and but not all infections are treated the same way. For example, pneumonia can be virus or bacterial, and these are treated in a different way. If someone has a virus and a doctor gives that person antibiotics it might actually make her or his sicker. In the states doctors do blood test, x-rays or many other tests that help them to properly identify what type of pneumonia children have. She recommended to studied at different types of pneumonia:
Staphylococcus aureus
Bacillus anthracis

Conclusion:
Based on her experience is not possible to diagnose pneumonia without x-rays or lab cultivation test. There is not one single protein to incorporate into a device that will help us to do a positive diagnostic.

More information:
http://med.stanford.edu/profiles/Nanci_Yuan

Assign tasks for writing
Background:

The General Idea:
In order to find out what is wrong with a patient, he asks several questions. The questions could branch out in different directions from general to specifics.

How important is to know the breathing rate of a child in order to determine if he or she has pneumonia?
Since he was not a pediatrician or an expert on the subject, he said that he wasn’t sure. However, personally he will not make a diagnostic based on that single factor.
He recommended looking at scripts that companies such as Kaiser have for patients that call in and see what questions they asked to make a diagnostic.
It is very important to look at patient history and how the patient looks, for instance look if he patient has blue or purple lips.
Also, look at combination of our symptoms (how we test) since we could be mislead us to false result.

More information:
http://www.stanford.edu/group/liaolab
Title: Exploring global health diagnostic criteria

Date: February 11, 2013
Location: by phone
Name: Dr. Adam Hoverman, DO
         Associate Professor of Family Medicine and Global Health
         Pacific Northwest University of Health Sciences

Background:
The general idea:
In a structured, clinical setting, most doctors use a ‘tree’ style diagnosis algorithm. When a patient exhibits a particular symptom, this leads to inquiries about other symptoms, and so on. However, an untrained health worker does not have the kind of expertise to determine what they should look for if a particular symptom appears. Therefore, the WHO has created the IMCI guidelines to provide a somewhat streamlined approach for health care workers who do not have as much formal training as one would encounter in a first-world setting.

Title: Ade Mabogunje Interview – General information about Nigeria

Date: January 29, 2013
Name: Ade Mabogunje

Background: Professor at Stanford University

The general idea:
The discussion was mostly related to travel to Nigeria, but also involved discussing ways of making “hidden” discoveries during a field visit. Some ideas included:
- Meeting with the local “shamans” to better understand the religious medicine being practiced in the area
Looking into the ways that a local healer deals with these diseases. If they work, are there any medical strategies behind them?
Could these healers be utilized for a potential solution?
Solutions will be embedded in the stories told by the people
Understand local words. For instance, what is the local word for pneumonia, where did it come from and what does it mean?
Any solution requires the solution to meet the people at their level, as opposed to the people having to meet the requirements of the solution

Other contacts: Ndidi Endozien – located in Nigeria, Prof. Sade Ogunsola – located in Lagos (sister)

Title: Tim Akinbo – Cell Phones and Mobile Technology in Nigeria

Date: February 1, 2013
Name: Tim Akinbo

Background:
Software developer in Nigeria. He has worked with food and nutrition as well as child protection (birth registration) in order to build solutions that accumulate data utilizing mobile networks. Also built an app for people who distribute malaria bed nets in order to better report bed net registrations.

The General Idea: About his experiences with mobile phone technologies:
Most solutions utilize rapid SMS, due to the low amount of data usage relative to its speed and reliability
He discussed his current work with the National Population Council and UNICEF that uses rapid SMS to register child births.
Program had some small incentives to encourage participation, from as little as covering the cost of the messages to making it mandatory to report for all National Population Council employees.
Most phones are “dumb” phones (calls, text), with a decent number of feature phones (camera)
Next wave of phones have the internet, but these are a few generations behind the U.S.
Blackberry is #1 smartphone, but Android growing rapidly
Phones get passed down through the income levels, but government workers are typically on the low-end of the salary scale
Title: Jeremy Canfield: E-reporting and SMS

Date: February 8, 2013
Name: Jeremy Canfield

Background:
Works for ReBoot, a service designer trying to connect NGO’s to beneficiaries. Currently working on a social accountability tool (My Voice) that uses rapid SMS in Nigeria. The project is a pilot program through the World Bank.

The General Idea: He discussed his prototyping experience and the pilot program. He also discussed the issues his team faced, and potential solution spaces relating to mobile technology, including:

· The solution cannot simply assume network connection, or that a device can be charged. He suggested that when making assumptions of the available resources, “be a pessimist”
· If a phone is utilized, think about ways to cache data, as the network is spotty and varies depending on location (in urban settings)
· The time required to scale a project is very different than the timeframe to implementation. For implementation, it must work immediately, but scalability can take up to 5 years
· Make sure that prototype works, with no bugs, before taking it to the field. The knowledge gained in the field is much more valuable if problems that could have been found at home are weeded out.
**Background:**

Based in Lagos, he formerly practiced as a medical doctor, but is no longer doing so. Faculty at The General Idea: The discussion was mostly a general survey of questions about Nigeria. He addressed issues related to travel, health diagnostics, mobile technologies, and other general inquiries. The main topics that were discussed included:

- Reading peer-reviews in order to augment the information gained from UNICEF reports
- Potential travel destinations; he mentioned that John's Hopkins University has a center in Ife, which is close to Ibadan.
- Do not look at smartphones; SMS-based solutions are preferred due to their ability to be more scalable, less reliance on data networks, and the phones available to the public
- For every one person that goes to a health center, 10 will not
- Any solution has to reach the actual users at their level
- Little, small interventions occur over and over, so a successful solution needs to build on that
- There will be little excitement for a diagnostic device, as the people constantly see pilot programs that never materialize
8.2 Benchmarking

8.2.1 Product benchmark posters

**ELEPHANT-TAP**

**Problem:**
Water, sanitation and hygiene in schools in Uganda

**Solution:**
A locally made tap, teaching appropriate time for hand washing (20-30+ sec.) and cutting the path of the germs by preventing the recontamination of hands.

**Results:** So far positive results from user testing: children loved using the tap, preferred it over the old ones.

**Status:** Prototype

**Challenges:**
- Local manufacturing
- Finding components in Uganda that wouldn’t rust

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**Embrace**

**Problem:**
20 million low weight/ premature birth babies are born every year, 450 die every hour.

**Solution:**
Low cost incubator: The device’s technology bundles a sleeping bag with a warming pack and heater.

**Results:**
Won the fellowship at the Echoing Green competition in 2008 for this concept. Embrace also won the 2007-2008 Business Association of Stanford Entrepreneurial Students Social E-Challenge competition grand prize.

**Status:**
Launched 2011, providing medical support to more than 300 babies in rural India. 2012, plan to scale up the distribution of Infant Warmers to serve 100,000 newborns and their families in impoverished communities.

**Price:** ~25 $ (traditional incubator 20000 $)
Problem:
One child dies every 15 seconds due to lack of basic sanitation.

Solution:
Disposable bags that sanitize the feaces, so that they are safe and can be used as fertilizer.

Results:
93% continued to use the Peepoo after their first try.
The user acceptability tested in both urban slums and emergencies. All evaluations indicate high user acceptability, in different cultures and conditions.

Status:
Used in in the Kibera slum, Kenya
4500 regular users. The Peepoo system has also been implemented in more than 30 schools in the Silanga area in Kibera.

Price: 0.0184 €/bag

Problem:
Every 15 seconds a child will die as a result of drinking unsafe water.

Solution:
Portable water filter that effectively removes all bacteria and parasites responsible for causing common diarrhoeal diseases. 1,000 liters of water = 1 person/one year. Family version 18,00 liters = 5 persons/3 years

Status:
Manufactured by Vestergaard Frandsen
Is available for retail sale in the developing world, but the majority of LifeStraw for free in the developing world eg. LifeStraw and LifeStraw Family were distributed in the 2010 Haiti earthquake, 2010 Pakistan floods, and 2011 Thailand floods.

Price: 3 $ / 17 $

Challenges: Acceptance. 'Family size' more traditional filter ended up being a lot more popular.
8.2.2 Sanitation Hackathon, Helsinki: Mobile Neuvola for the Developing World

The Aalto team participated in the Sanitation Hackathon in Helsinki sponsored by the World Bank. During the event, the team worked on testing the idea of taking the Finnish ‘Neuvola’ (described in chapter 4.3.2) to the developing world using mobile technology.

The basic concept was to prototype / mock-up an application for the Community Health Workers (CHWs) which would help them in providing ‘right information’ at the ‘right time’ in the ‘right way’. In particular, the following two main uses were visualized:

- Community Health Workers have access to regularly updated content to educate themselves and the local people / mothers etc. on three key areas or tenets of the Neuvola system (when it was initially pioneered). i.e
  - Sanitation and Hygiene
  - Nutrition and importance of breastfeeding
  - Immunization

- CHWs can keep track of their households’ medical history and be more efficient and effective during their interactions. The application would provide them with simple checklists to follow, both for regular scenarios as well as for exceptional cases (e.g. when a child has diarrhea). The checklist approach is intended to help the CHWs to make the right decisions and also track medical history at a granular level. The data collected as well as the medical histories can also be shared with the regional health care centers or other organizations for further analysis.

![Figure 24: Home (first) screen](image)

![Figure 25: Educational content](image)
Concept screenshots / mock-ups

The first screen (Figure 24) presents the CHWs with two options. They can either go into the ‘Education’ section, in which case they are presented with educational content pertaining to the key tenets as mentioned above (Figure 25). The ‘Keep Track’ option takes them to a view where they can see the scheduled visits for the day. Delving deeper into each scheduled visit, the users can view the profiles or the ‘Health Calendar’. The health calendar (Figure 26) highlights the current visit, where the CHW can access the checklist for the day and also the medical history. They can also navigate to past dates to check the historical data or future to schedule new visits, set up alerts etc.

Figure 26: Health calendar
Finland has one of the lowest child mortality rates in the world. We visited Kätilöopiston maternity hospital in Helsinki, Finland to benchmark how complications during the birth are dealt with. This also gave us perspective for our travel to Nigeria, when we visited delivery rooms in healthcare centers in Nigeria.

Kätilöopiston Sairaala is a hospital focused on childbirth and gynecology, and also functions as a teaching hospital to midwifery students. 5700 births occur there every year and they have 17 delivery rooms. We interviewed the head midwife of the birth department. We were especially interested in the equipment and we wanted to find out if we could possibly create more affordable versions of these equipment.

Our main insight was that in general the equipment was very expensive: Even a regular delivery bed costs several thousand dollars. The most important technological tool in modern delivery room for the midwife is the EFM Cardiotocograph (Figure 10), a machine recording the fetal heartbeat and the uterine contractions during pregnancy, and that costs “as much a small apartment”. 

The cheaper version of the EFM machine is a “horn” in figure 11. Before CTG midwives used the “horn” to listen the baby’s heartbeat. By listening where the baby's heartbeat was coming, the midwife could also determine the position the baby was in. However, to be able to use the horn correctly the midwives needed a lot of training and experience.

Figure 10: EFM, Cardiotocograph

Figure 11: A “horn”, a cheaper version of the CTG machine. Later in trip to Nigeria we found these kinds of horns in Nigerian delivery rooms too.
The most important equipment, according to the interviewee, are the scissors needed to cut the perineum and instruments needed to cut the umbilical cord (figure 12). If the perineum rips uncontrollably it can cause serious health problems in the mother. The cutting of the perineum is done in about 18% of births, e.g. when the baby is big or in an instrumental delivery. Instrumental delivery is needed when the contractions are bad and when the delivery is prolonged making the mother more and more tired. The instruments used for this are suction cup or tongs. A doctor is needed to operate the tongs and the use of the tongs is quite rare.

We learned that one of the cornerstones of Finnish maternal care is prevention. The complications are often preventable by early and continuous monitoring and by educating the mothers. For example antibiotics are given by default to avoid infections. We also learned that the estimation of the time of the birth is extremely inaccurate. It’s almost impossible to tell the right time beforehand. This highlights the importance of easy and fast access to the delivery facilities.
8.2.4 Neuvola - The Finnish Maternity Clinic

One of the most interesting benchmarks we have found is Neuvola. Neuvola is the Finnish maternity system focusing on mother and child health. The reason why we got so excited about Neuvola was the fact that in only five years under-5 mortality dropped from ten percent to four percent after the nationwide implementation of Neuvola system in late 1940’s. It was not because of economic development or more advanced medical treatments.

Neuvola was based on the idea that mother and child need special attention. Neuvola’s main function was to deliver the right information about child care to the mother at the right time and in a personal way. Neuvola focused on three topics: hygiene, nutrition and vaccination (Figure 13).

- **Hygiene**: mothers received information how to wash the babies and what is the right level of cleanliness.
- **Breastfeeding**: mothers were told the importance of exclusive breastfeeding as the source of nutrition for the children. Breastfeeding is the best way to nourish the child and develop the immune system.
- **Vaccination**: Neuvola also educated mothers about immunization and provided the vaccinations for the children.

The Neuvola system also monitors the condition of mother and the child, and they visited Neuvola clinics regularly and often.

Our idea is that could we use the same principles that were used in Neuvola and apply them in a 3rd world context. In chapter 4.6 we present a concept that we have been developing.

*Figure 13: Neuvola focused on sharing information about hygiene, nutrition and vaccinations*
8.2.5 Beads

Motivation:

In order to fully understand how current health workers diagnosed pneumonia, we decided to reproduce their method. Healthcare workers use a combination of a 60-second timer and a string of beads to count the respiratory rate of the sick child. If the respiratory rate is elevated, the child is treated for pneumonia.

Description of the Experiment:

We reproduced a bead necklace similar to one that healthcare workers currently have. It consists of five different colors with ten beads per color (Figure 14).

Conclusion:

The clicking of the timer is distracting, and the beads only evaluate one possible symptom of pneumonia. A healthcare worker easily loses count of the beads. Since the beads look like the healthcare worker is holding a rosary, it seems that healthcare worker is praying and he or she loses credibility. Also, this method requires children to lie down and be still, which can be difficult to accomplish. Finally, an elevated breathing rate is not necessarily the only symptom of pneumonia, and doesn’t make for a foolproof diagnosis.

Figure 14: Counting beads
8.2.6 Understanding The Use of Mobile Technology

**Motivation:**
In order to build something that requires almost no power and minimum knowledge of technology, we decided to explore how mobile devices are being used in Nigeria (Figure 15). In order to understand the impact and the use of cellphones, we did several expert interviews, collected data, reviewed current and obsolete mobile technology, and analyzed prices for voice and data plans.

![Figure 15: Mobile phone use in Africa](image)

**Cost and Accessibility:**
The use of mobile devices is very common in third world countries; however, it is more common for a man to have access to a cell phone than a woman. People with higher socioeconomic status will get the newest models on the market, and when a newer model is released, he or she will pass on (or sell) his or her old cell phone to her friend (more than likely someone from a lower socioeconomic class). Most of them know and use text messages services, and many of the users are in pre-paid plans. There is a very limited access to data, and usually it is very expensive.

**Government and Mobile Technology:**
Many government organizations use the mobile technology to collect information from their populations. For instance, UNICEF has a program in Nigeria called “U-Report” which consists of asking their citizens to send a text message immediately after they see a crime. This service is free of charge and it has helped to reduce crime and allows them to know which areas need more security.

**Conclusion and Lessons Learned:**
Initially, we thought of developing an app that would help healthcare workers in diagnosing pneumonia. However, data for cell phones is still very limited and expensive in third world countries. Moreover, the phones that could possibly run apps are almost nonexistent there. Many of their phones would be considered non-smart phones.
8.2.7 Crowdsourcing

Motivation:

In order to increase access to medical and wellness advice for the most remote communities in third world countries, we needed to find an effective distribution channel. The cost of hospitals or local clinics is a major problem in third world countries, and access to specialty doctors such as a cardiologist or a neurologist is almost impossible and limited only to the upper class. Therefore, we started connecting it to the medical school system in the first world countries. We discovered that doctors go to medical school for many years, and even after becoming experts in some areas many times they decide to go back to school to become surgeons or more specialized doctors. We decided that it could be possible to connect many of these residents or doctors with individuals in third world countries that are in need of their skill sets.

The general idea:

We will utilize the same model that many online companies use by advertising “online doctors.” The general idea is that a healthcare worker handling the patient would send a text message with what he or she visually saw the problem to be. Then, that question (or that problem) will be visible to registered healthcare professionals across the world. One of them would answer the question, and the response would be delivered via text message (Figure 16).

The people needed:

A very large network of doctors, resident students, and experts on the medical field.

Conclusion and Lessons Learned

Even though this seems like a great idea at first, we soon run into major liability issues. Even though doctors will be giving advice only and it is up the healthcare worker to decide if the advice is appropriate, it will probably be the doctor’s referral that the healthcare worker follows. If the patient dies, the doctor as well as the healthcare worker would share responsibility. Furthermore, it was difficult to find funding to offer incentives to doctors that answer questions.

Figure 16: Crowdsourcing process
8.2.8 Malaria Test

Motivation:

In many ways malaria is similar to pneumonia. Both of the diseases are preventable and treatable if they are detected on time. Early diagnosis and prompt treatment are key elements for the patient's full recovery. If not caught in the early stages, it can lead to major health complications or death.

Before there was a test to detect malaria many people tried different techniques in order to prevent children from getting infected. Among these techniques were: bed nets and repellents. However, none of many ideas seemed to work. For instance, the bed nets were very uncomfortable to sleep under and people were not using them. Repellents were expensive and people forgot to apply them in daily basis.

Test:

Currently one of the most effective ways to detect malaria is by using a test (Figure 17). This test is disposable and it shows either a positive or negative result almost instantly. In many ways this helps the patient to understand if he or she needs to seek immediate medical attention. The test itself is affordable and it only requires a drop of blood from the patient.

Conclusion and Lessons Learned:

In many occasions, when we were reviewing how to diagnose pneumonia, we tried to segregate specific symptoms. However, after an extensive review of the information, it was not possible for us to determine one single test that would allow us to diagnose pneumonia in the same way that the malaria test works. In the first world countries when patients have blood drawn to see what type of pneumonia they have, doctors are able to determine treatment by analyzing the composition of the blood. Each variation of pneumonia is classified by the type of protein that shows up in the results. The most accurate way to diagnose pneumonia currently in first world countries is by doing an x-ray exam, which is very expensive and not available in many of the community centers in third world countries.

Figure 17: Malaria treatment kit
8.2.9 River Blindness Treatment

We interviewed Dr. Oladebo, head of the department of Health Promotion at Ibadan University, on the project he did for fighting against Onchocerciasis or River blindness. River blindness is a disease caused by a parasite that untreated will eventually cause the victim to become completely blind. It is especially a big problem in the rural areas, since the logistics for the medication and health care personnel are difficult. Dr. Oladebo’s innovation was to create a system that would train the members of the community to distribute the medicine themselves.

The parasite can live inside the victim for up to 8 years, a time during which he needs to take the medication once a year. The dose of the medicine is variable, and is dependent on the patient’s size. In Dr. Oladebo’s system, few trusted members in the community were trained to be the medicine distributors: He provided the community trustees with a stick with lines that indicate the amount of suitable medication dose for a person based on their height (Figure 18). The system also includes bookkeeping of the medicine with tally marks, that he had observed that the villagers use in other accounting in their daily life.

With this community directed solution the river blindness was managed to get under control all around the Africa.

Figure 18: River blindness tablet scale on the wall.
8.3 Sanitation Prototypes from the Fall Quarter

Dumping the Waste

The first prototype was built to carry out a series of tests in order to determine if a safe, sanitary, and easy way to dispose-off waste from an in-home toilet system was achievable. Similar to the coating applied to ketchup bottles (see figure below), if we could make the disposal surfaces “non-stick”, it’d make cleaning easier and hence encourage the users to use the product. It would also help with sanitation related issues by minimizing contact with the waste.

Notice that there is no residue left in the bottle.
Figure 13a: MIT ketchup bottle test

Large amount of waste still present after dumping
Figure 13b: Residue when container lined with graphite

A silicone lubricant made the process much cleaner
Figure 13c: Residue with container lined with silicone lubricant

Separating the Waste

Three versions of another prototype were also built in the form of a filter-based design. The idea was to separate liquid and solid wastes using a ‘shelf’ which would effectively ‘strain’ the waste. Absorbent materials were added to the shelf (cat litter, moisture absorbing crystals) in order to dry out the solid waste.

Based on the test results, we realized that while the absorbent materials might indeed prove useful, there were several other obstacles that hindered this specific filter-based design from working out well in practice.

Figure 14a: Moisture-absorbing crystals did not filter as well as expected; water pooled on top of shelf

Figure 14b: Cat litter clumped as expected

Figure 14c: Side view of the shelf-filter design

Visualizing the bacteria

This prototype was aimed at exploring the possibility of devising a way to visualize bacteria contained in the hands to children in order to sensitize them to handwashing. The justification for this emanates from one of our expert interviews where the interviewee pointed out that since
children (and even adults) could not actually ‘see’ that their hands were dirty or had bacteria, they did not find it imperative to wash their hands.

We discovered a commercially available product called GloGerm’s ‘HygiKit’ which can be used to simulate the effect using a excitable liquid / powder and UV-light. We managed to obtain a sample kit locally. In our CFP we used only the UV-light and the GloGerm liquid. The critical function was to find out if we could actually visualize the bacteria effectively and affect the kids’ mindset using the kit when exposed to UV-light using in a dark box or room.

We didn’t order the the specialized dark box, but the dark room worked well. Our critical function prototype test users were Otaniemi kindergarten kids around the age of three to five. The test included several steps and got the children quite excited. First step was to rub the orange liquid into their hands so that it was almost invisible. Then we made every one wash hands in the normal way and made a check if there were any bacteria. Most of the hands showed significant amount of glowing colour. Next, we repeated the same steps - rubbed liquid into the hands and washed them. Only, this time the children were informed and instructed about bacteria and to wash their hands in the proper way. In the last UV-light check less “germs” were visible, thus emphasizing the effect of washing hands properly.
Test users (not from our test). The spots with liquid residue glow in dark under UV-light.

The critical function prototype was not working as expected, since it didn't show the bacteria itself. On the other hand it worked as a revealer for the spots which were washed sloppiest and in that way also showed the most unclean, germ rich, spots in hands.

The Glo Gem Products had already been tested as helping devices in Developing countries hygiene education.

Questions to be answered:
• Can the Glo Gem show bacteria on hands?

Figure 16: Pictures showing Glogerm used in a classroom [13]

• Is the gel safe?
• Is it easy to use e.g. wash it away?
• Can users understand that they have bacteria on hands?

To Explore
• Originally we wanted to find out if the gel can show the bacteria
• The gel couldn't show bacteria, only the unwashed spots on hands, so we looked functionality of that action
• We searched the function when hands are well washed and when the gel is seen on hands.

The Prototype:
• Glo gel bottle to measure out the gel for user
• how long the gel will last, amount of users per bottle
• Is safe to wash off and easy to use
For one of the critical experience prototypes (CEPs), we decided to explore the issues associated with using a “chamber pot” type device in the home as opposed to a public latrine or a more conventional flush toilet. For several days, one of our group members used the ‘Luggable Loo’ camping toilet and CleanWaste sanitary bags in lieu of a conventional flush toilet in order to discover the benefits and drawbacks of this method of sanitation firsthand.

Figure 17: The ‘Luggable Loo’ camping toilet by Reliance. The toilet consists of a seat and a standard 10-gallon drywall bucket. The toilet is extremely low-cost (under $20), making it extremely suitable for the purposes of the CEP.

Figure 18: The ‘CleanWaste’ sanitary bag. The bag consisted of a biodegradable plastic bag attached to the toilet using the seat. The bag was filled with an absorbent powder to gel and deodorize waste, as well as make it easier to handle.

The experiment demonstrated that although a ‘chamber pot’ style device does work, and it is a more effective way of containing human waste than no sanitation system at all, there are still serious drawbacks to such a device that make it a less than ideal solution. If a device of this type is to be successful, these issues will need to be addressed and solved before it is brought to market, as the success of the project is completely dependent on user compliance.

**Stability**

- The toilet has a high center of gravity due to the shape of the bucket
- The toilet lacks any counterweight or other device to increase its stability, and it only stabilized by the weight of the contents.
- This instability could create a problem for the very old or very young members of the user base. Parents will be reluctant to toilet train their children if there is a high risk of the device tipping over and creating a mess, and the elderly may not use it for fear of falling over and injuring themselves.

**Height**

- Shorter than a conventional toilet, the camping toilet is uncomfortably low to sit on for a full-grown adult.
- In addition, the device is too tall for small children to get up unassisted: this, combined with a lack of stability, create potential for a number of problems.
- The low seat could also cause problems for the elderly, who could have difficulty getting up once they’ve sat down. This problem is solved by stability bars and other assistive devices in the first world, but these devices will likely not be in place in the target market.

**Seat shape**

- Much smaller and rounder compared to a traditional toilet seat, which is oblong.
- The size of the seat means that the user lacks thigh support when sitting for more than a few
minutes at a time, which causes uncomfortable pressure points on the backside due to the user's weight being concentrated here instead of distributed over the thighs.
• The small size of the seat also exacerbates stability concerns.

Waste containment mechanism
• The idea of separating the containment mechanism from the device itself (i.e. having a separate part that deals with waste containment) has merit. It makes transporting the waste much easier, and cuts down on mess.
• The waste containment mechanism will have to be designed with end processing in mind. While the bag design was useful for containing the waste, as well as bio-degradable, it would not be particularly helpful in facilitating waste processing.
• Separating liquid and solid waste might also be a valid option. Most odor issues stem from the presence of solid waste, and being able to dispose of it more frequently (or more effectively compartmentalize it) may help with further reducing odor.

Emptying
• The user must simultaneously hold the bag and take off the seat, which is a press fit. This is very difficult to do with one person, and causes increased risk of contact with the waste, which raises the risk of disease.
• Carrying the bag to the proper waste disposal receptacle is unpleasant as well. The final device will need a way to make this task less disagreeable for the user, so that they are motivated to do it regularly.

Privacy
• Since the unit isn't self-contained, privacy isn't available just by virtue of the features of the unit itself.
• This could be an issue in one-room setups, as there is nowhere to put the device that is out of view of the rest of the home.

Unwieldy
• The toilet itself is awkwardly shaped and rather large, making transportation of the container as a whole an issue. Therefore, it is likely that the final design should be such that the entire device does not have to be moved in order to dispose of the waste.

Odor
• If bags are changed regularly, the odor is manageable, and each bag can be used multiple times before it becomes an issue.
• The presence of a lid also helps control odor, and keeping the lid closed when not in use is key to keeping the experience as pleasant as possible.

It is important to note that many of these observations stem from issues due to western cultural practices when it comes to using the restroom (such as the preference for sitting toilets over squat toilets, and the need for privacy). These issues must be further investigated: both from the standpoint of the target country, and among potential users who are more familiar with these cultural conventions.
Making soap

For our second critical experience prototype we wanted to explore the experience of making soap to test if the process would be easy and safe enough to be replicated in schools in developing countries. From our interviews we got the insight that often times in Uganda and in the neighboring countries there is not soap in homes, schools or even in NGO offices.

We wanted to test the soap making process to find out if it was easy and cheap enough for the children to do at school so that it would increase the availability of soap and simultaneously create ownership over hygiene. We have learnt from the expert interviews that ownership is one of the key success factors in changing behavior or adapting products. We chose NaOH process since it is easier and faster than creating lye and it also creates more solid soap that is the preferred form of soap in Uganda. We tried the soap with two different oils. The exact recipes and a list of equipment can be found in Appendix 8.4.

The procedure

1. The ingredients were weighed with an electronic scale
2. The water was mixed with the NaOH pellets that dissolved into the water by mixing.
3. The oil was added to the mix and mixed with a stirring device.
4. Optional, the color was added
5. The mixture was poured to the milk carton to solidify for >24 hours.
6. The next day the soap was cut into pieces.
7. The soap is ready to use after 1 month
All the measurements were really precise. For example measuring exactly 272 g of water required a steady hand and a lot of focus. We did not test how much the variation can be before it starts to have an effect on the quality of the soap but according to our instructor the variation can be only few grams. When the NaOH pellets were added to the water it created bad smelling fumes that are also not that healthy to breathe. The chemical reaction made the mixture very warm. All in all, the process of mixing the ingredients took one hour for two makers and one instructor.

**Results**

The conventional soap-making process is too demanding for our target conditions to be effective enough to make real impact. Even adult users felt unsafe from the fumes and the dangerous substance. It required a lot of concentration and accurate measuring even for adults even though it was considered ‘fun’.

One of the problems was that the soap remains unusable, and not safe to touch for at least one month. In African context this would create a real problem in the sense that there is often not enough room even for the classes let alone to store the soap for months.

In conclusion, the team feels that the conventional process is not fit for adoption in the target context. We need to consider alternative ways and methods if this has to be pursued further.
8.4 Information Management and Pneumonia
Prototypes from the Winter Quarter

The Dark Horse prototype was a chance for the team to test wild or ‘edge’ ideas that don’t necessarily completely fit into the focus of the project. The goal of the dark horse mission was to get inspired and obtain unexpected insights.

8.4.1 Measuring Babies

Motivation
During an observational visit to Neuvola (as a continuation of our exploration of adapting the success of Neuvola in sub-Saharan Africa), we noticed that measuring and recording vital statistics (baby’s height, weight and head circumference) was a routine task. These measurements, compared against the standard benchmarks established by WHO (World Health Organization), are meant to aid early diagnosis of any health problems that the baby might have. For example a sudden drop in the baby’s weight is often a sign of sickness.

Our first idea for the dark horse derived from these observations. We visualized a device or tool that would make measuring the above noted vital parameters of the baby “idiot proof” to enable measurements and tracking at home by possibly illiterate, without the tiring and time consuming trip to healthcare center, which, in African context could be tens of kilometers on foot.

Prototype and testing
We identified the measurement of the height and the head circumference (OCR) as more complicated compared to weight (even in Finnish Neuvola context, two people were needed to measure height) so we started prototyping ways to accurately and easily make those measurements.
Our first prototype was inspired from the traditional baby height measuring board, but it had straps to hold the baby in place instead of needing two people (Figure 28).

However our preliminary reactions from “users” (non-users trying to imagine from the perspective of users) suggested that it might not be very desirable to strap the baby in a machine.

The second prototype was about measuring the baby’s height the same way as older children and adults - standing up (Figure 29). The prototype consisted of specially made, pre-calibrated shoes with magnetic soles. The magnets in the shoes help hold the baby stable so the measurer only needs to support the baby with one hand, leaving the other free for measurement.
8.4.2 RadioMama

Motivation
As already noted, one of the key learnings through background research and needfinding had been that lack of information was a major underlying reason for child mortality. We narrowed our focus to three categories and solving one or more of them would have significant impact:

1. Sharing information about hygiene, nutrition, immunisation and illness treatment with the mothers would prevent illnesses and empower the mother to react properly if illness occurs. This is also in line with our discoveries related to Neuvola, the Finnish maternity care system.

2. Helping community health workers to do right and quick diagnosis would lead prompt treatment which would save lives.

3. Measuring and tracking the appropriate data points about mothers and children would allow community health workers to focus on most critical issues and learn which practices are actually proving to be useful. If the data is collected in a usable way and format, it could help in quick decision making.

The RadioMama dark horse prototype was a gauge to test if a radio-like device and service could be an effective way to share information with the mother.

Description
The core idea we got from our brainstorming (Figure 30) was to have a dedicated, minimalistic device - a ‘Neuvola at Home’ that establishes an ‘always-on’, two-way communication channel between mothers and the healthcare system. The device plays messages sent by community health workers to mothers. The messages are information related to mother's and child's wellbeing, actions needed to achieve this and notifications on upcoming health related events (e.g. vaccination days).

We tested two different prototype devices with different interaction philosophies and interfaces:

1. A mobile “box” that plays periodic messages automatically, without the mother interacting the device in any way. The form-factor is similar to a cellphone and hence can be carried around easily by the mother (Figure 31).
A radio-like “box” that requires active interaction from the mother (e.g. by pressing a button) to hear the messages. The idea is also to engage the mother with the device in different ways (e.g. pictures, calendar, game) in contrast with the other prototype which is designed to not require any active engagement (Figure 32).

We wanted to know which one was a better way to convey information. We tested this by asking the users to reply to a simple questionnaire (see appendix 9.4) after using the device for stipulated time (1 hour).

**Conclusions**

The prototype and the tests failed to yield much substantial or usable insights. This failure could be attributed to multiple factors. For instance, the test should have been more focussed and better designed and should have been carried out with the right and more users. We managed to have only a few tests within the Design Factory environment - which was not representative of our target context and user group.

The data from testing was inconclusive with mixed responses towards the RadioMama concept overall. For example, while most users remembered at least part of the information conveyed they were lukewarm at best towards having to carry or use an additional device and especially about long-term usage of the same.

However, the prototype did provide good meta-learning for the team about test planning, design and selecting test users.
8.4.3 Crowdsourcing in Pneumonia Diagnostics

Motivation

By the time we were confronted with the task of making a Dark Horse Prototype, we were already shifting focus from sanitation to information space and specifically diagnostics. Therefore, we began looking into novel ways to go about diagnosing a disease, preferably methods that had been dismissed as un-doable. One of those methods was inspired by the CHW’s themselves; that is, using relatively untrained people to create a first line of evaluation. This led to an idea that perhaps we could utilize crowdsourced diagnoses that could potentially provide as accurate a diagnosis as that from a trained health professional.

Our crowdsourcing idea gained traction when we discovered a study that indicated that using a community-based method of diagnostic procedure was nearly as accurate at diagnosing malaria as the procedure involving trained health professionals [16]. To further evaluate the idea, we outlined the proposed solution process, and all that would be involved in order to make it a viable solution, which can be seen in Figure 33.

Using this diagram, we identified the most likely points at which this process could fail. We identified two major failure points: the ability to enter symptoms easily and accurately, and a potential lack of motivation for our “crowd” to participate in this service. By identifying these potential points of failure, we were now able to design prototypes that could test to see if these points of failure were manageable.
In addition, we outlined a model for how the crowd would be organized. It would consist of regular users, medical students, and trained medical professionals. We would aggregate the data from their individual diagnoses and weight each diagnosis based on the background of that member of the crowd. In effect, we would be weighing the opinion of those with medical experience more than that of regular people, but we would have the expectation that more regular users would use the service. This weighting idea is represented in Figure 34.

Description
In order to test the step involving an input of the symptoms, we decided to make a web-based application that would act as a sort of questionnaire, allowing the user (whether this be the health worker or the child’s caretaker) to input symptoms. This would simply be integrated into the phone, since we would be needing a phone in this sort of system to transmit symptoms to our crowd. The general layout of each question in the app can be seen in Figure 4.8.3-2). The app included a series of questions (the series was adaptable based on previous answers), and each answer had a “yes” or “no” button. A “maybe” button was also added on many questions that proved difficult to answer definitively.
Designing a Test

In order to test both our device, as well as our theory that the accurate input of symptoms would be a problem which we would need to overcome, we designed a test procedure that we felt somewhat resembled what a caretaker or CHW would encounter in the field. Because we did not have access to real children, we showed our test subjects a video of a child (there were two different videos; one with a child sick with pneumonia and one of a child with a different malady). After watching the video, our test subjects were prompted to input the symptoms based on what they observed, as illustrated by Figure 35. Based on the inputs, the app could recommend a course of action. For the video of the child with pneumonia, if all symptoms were input correctly, the app would diagnose pneumonia immediately (without crowdsourcing). For the other video, the correct input of symptoms would lead to a recommendation to wait for 1 hour as the diagnosis was sent to the crowd for evaluation.

Key Learnings

- Some diagnostic terms were hard to understand or quantify for those who do not have experience in the health sector. Explanations helped.
- An hour was specified as being too long of a wait for results
- The app was more useful as a questioning tool, but at that point, what is separating it from a service such as WebMD?
- Most users had little confidence in their answers
- The “maybe” was necessary to prevent false diagnosis, but it also led to a lot of useless data if the tester selected this option too often
- Diagnostic tools to accompany the questions would be helpful
While many eventually input the correct symptoms, one user mistakenly identified the child in the non-pneumonia video as having pneumonia, due to some key symptoms that were mis-identified.

User Motivations Testing

While simultaneously testing our phone application, we were interested in seeing what could motivate everyday people, medical students, and doctors, to give their time to a service such as the one we proposed. Because of the nature of the cost constraints related to our project, any type of monetary reward service, such as Mechanical Turk, a crowdsourcing site that offers small monetary reward (e.g. 1$) for completing small tasks, would likely be too costly to maintain. Also, it would be key to get participants with some sort of medical experience, whether that be trained doctors or even simply medical students.

In order to see how participation in the program would be affected depending on different rewards, we conducted a study involving doing simple math problems on the web. Math problems were used because they provided a large amount of simple, short problems that still required a good bit of thinking. We divided the participants into four groups, as described below:

1. No reward - Control group
2. Monetary reward - $0.10 per completed question
3. Imaginary points reward - participants awarded one point per completed question, and all participants see a leaderboard showing their status in comparison to others as they leave
4. Imaginary points (leaderboard shown at beginning) - same as group 3, but the leaderboard is instead displayed before questions are answered
5. Donation - $0.10 donation to UNICEF per completed question

Through this testing we observed that the type of motivations had little impact on the performance of the users. In fact, those who were only receiving imaginary points and were able to see the leaderboard before they began actually answered more correct questions than any other group. However, the testing did not have enough participants to make any large conclusions, and we did not pursue this any further because we moved away from this idea.

Conclusions

- While it seemed like a novel idea, there is little separating this method of diagnostics from web-based services, such as WebMD, that already exist
- After more expert interviews who work with mobile technology in Nigeria, it is clear that the technology to implement this sort of solution is not yet in place. Though we could design for the future, networks would still likely be unreliable, putting the whole diagnosis at risk if network was unavailable
- Requires newer phones to which the CHW’s and caretakers do not have access
- Questionnaire idea is valid moving forward, but it might be beneficial to make the “app” less technology, data, and power-reliant
9.4 Dark Horse Questionnaire

Questionnaire

Info
- What is a good reason for laughing?
- What you need to do to get your daily calcium needs?

Actions
- Did you wash your hands before eating?
- Did you have a 5 min brake to stretch?

Pep Talks
- How did the device make you feel?

Event
- When and where is the free body fat measurement?
Did you find the device irritating?
Did you learn something new?
Does the device help you to memorize things better?

Overall / Experience Questions

Overall question is: Is a dedicated device with only audio and simple interaction interface a good way to share information and communicate?

Is the device irritating?
If you were given this device, where would you keep it?
Do you like the shape / size? Would you want something different?
Did you remember the information the device gave? (separate Quiz)
Did you knew intuitively how to use device?
Do you want to carry it around or keep it in one place?
How would you want to charge it? Test different options?
9.5 Interview guideline for BabyBook

Onko teillä tällä hetkellä käytössä minkäänlaista vauvakirjaa?

- Mikä motivoi käyttämään sitä?
- Täytätkö heti vai monta kerralla? kuinka usein?
- Minkällä muilla tavoin säilytatte tietoa vauvasta? Rokotuskortti, neuvolakortti?

Minkälaisia muistoja haluaisit säilyttää?

Miten koette, että samassa paikassa olisi sekä iloisia muistoja? (eka sana, eka kävely), että ikäviä (sairaudet)

Mistä asioista olisi hyvää olla tietoa kirjassa? Mitä tietoja saatte Neuvolasta, mitkä olivat hyödyllisimpiä?

Olisiko parempi käyttää päivittäin vai ei?

Onko muistojen säilyttäminen hyvää kannustee tietojen keräämiseen?

Haluaisitteko kirjoittaa muita asioita kirjaan myös?

Minkä kokoinen kirja saa olla, jos se pitää ottaa mukaan neuvolaan?

Miten muilla tavoin tietoa voitaisiin jakaa/kerätä äideiltä?