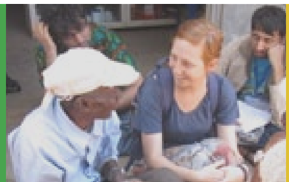
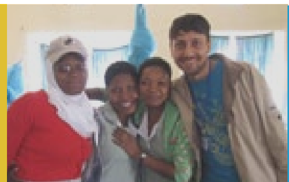
Final Documentation

ICT & Maternal Health

Index

Abstract

Anemia is one of the lead causes for hemorrhaging and maternal and infant death in Tanzania. An early assessment of Anemia would increase the likelihood of treatment and lower the risk of maternal death. Several diagnostic tests exist in the health facilities visited by us, but not in all, and require additional resources such as glass slides which are often not available. During IDDS 2014 tried to develop a smart phone application that increases the accuracy of the clinical diagnosis of anemia, in order to increase the availability of anemia diagnosis and lower the risk of maternal and infant death. All six team members expressed interest in continuing the project. Our next steps include developing a working prototype and exploring the accuracy of the proposed method through a clinical study.

I. Context

Background

Community Description

Problem Framing Statement

I. Context

Background

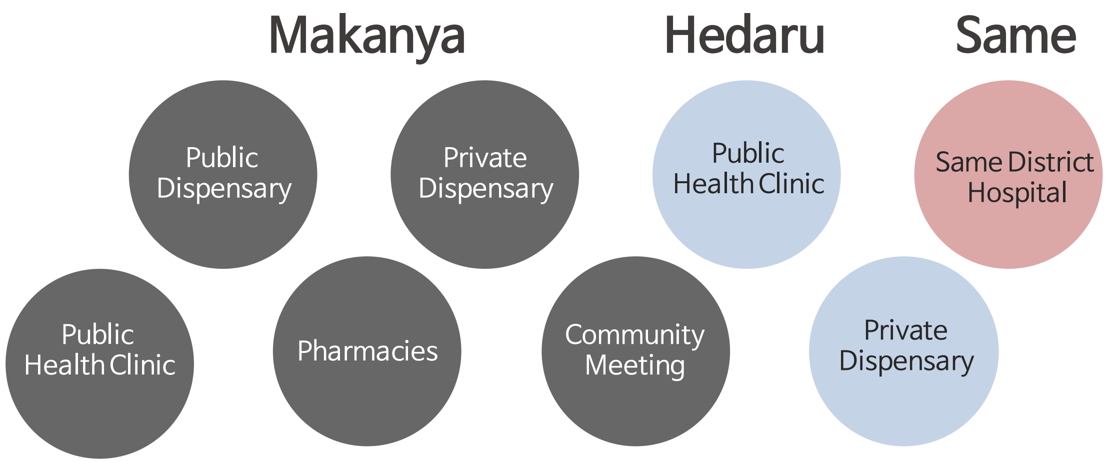
Information Communication Technology (ICT) is rapidly becoming more accessible in developing countries, increasing its value as a tool to promote development in many fields. In areas where health resources are limited, ICT can improve access to many services. One of the services that ICT has the potential to improve is the field of diagnostics. Anemia is an extremely common condition in pregnant women, the dangers of which are increased in areas with a high prevalence of malaria. This project aims to develop a simple, noninvasive test to increase the accuracy of clinically diagnosing anemia in Makanya village. The test is a smartphone application that has the ability to photograph and analyze the conjunctiva for signs of anemia.

I. Context

Community Description

Makanya village is in the northeast of Tanzania and has a population of around 10,000 people. There are various healthcare facilities present in the community with different levels of care. A public dispensary is located in Makanya village and has one doctor and several nurses. A public health center, slightly larger than the dispensary, is in the nearby village of Magwasi and also has one doctor and additional nurses. A private dispensary is also present in Makanya village and has at least one doctor, but requires an additional fee. Neither the public nor private health facilities have consistent access to diagnostic testing.

For any advanced healthcare service, all residents of Makanya must travel to the hospital in Same, about 30 miles away. Many residents of Makanya cannot afford to go to the private dispensary or Same.



⟨Summary of Community Visit⟩

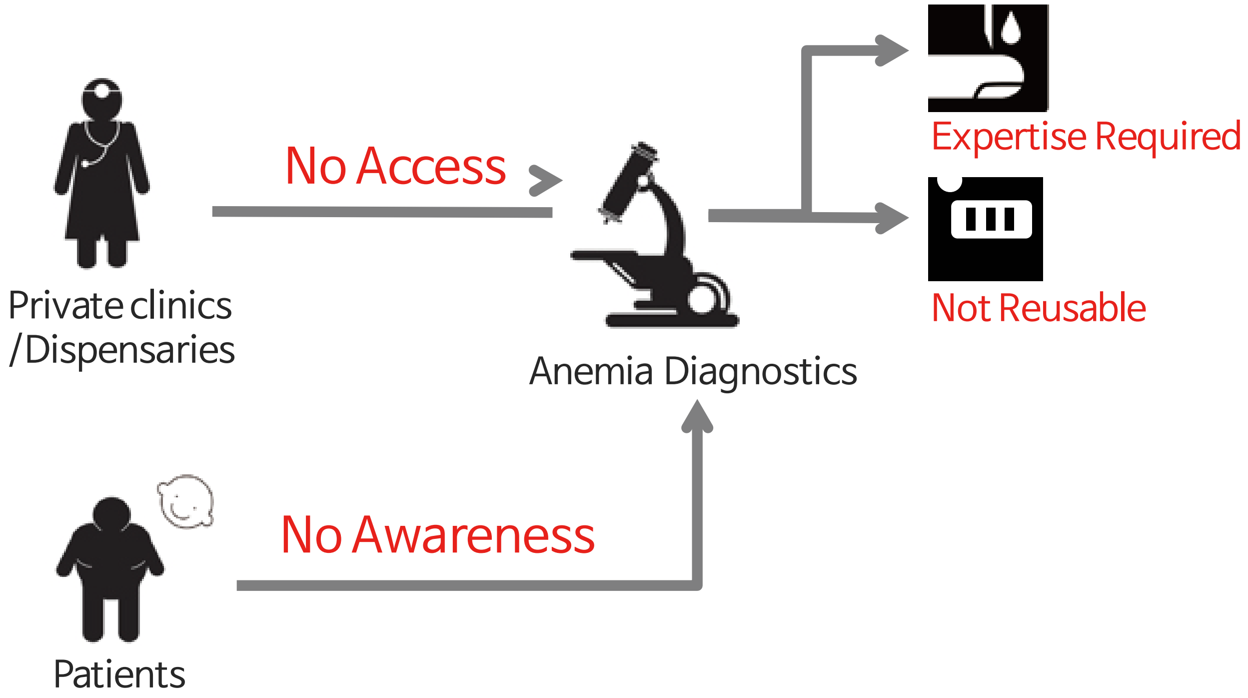
Additionally, there is a strong distrust of public health facilities. Because of this, many women in Makanya give birth in the home, sometimes with the presence of a birth attendant.

All public health facilities are almost exclusively supported by the Tanzanian government. However, medications and testing devices are often out of stock. Conversely private dispensaries have much more direct control over the facilities they provide. Because of this and the increased trust the community places in private dispensaries, the team has decided to focus on private dispensaries for the ICT for Health project.

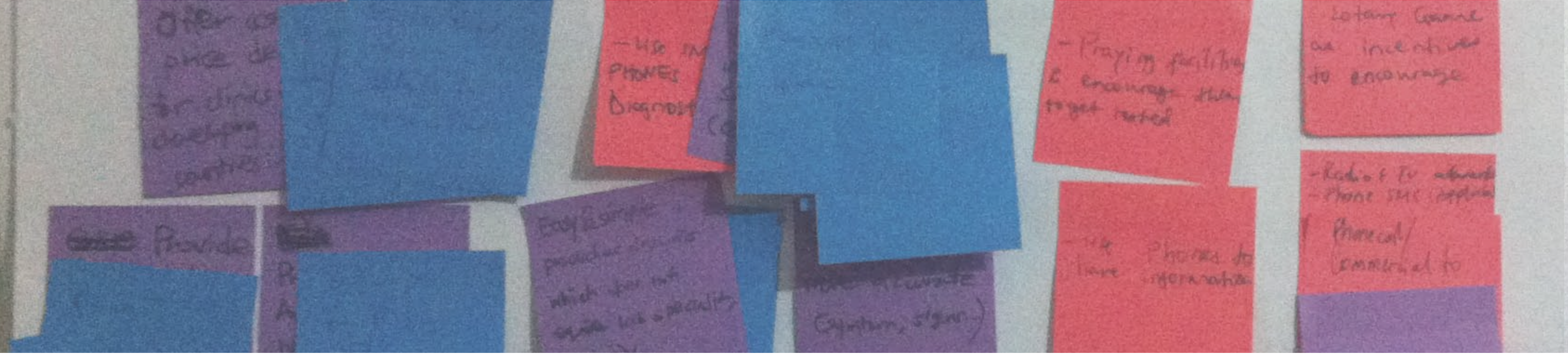
While access to healthcare services is currently very limited, access to mobile phones is quite high. All community members interviewed either own or have access to a mobile phone that regularly contains credit. This provides an opportunity for an ICT-based health intervention to improved health services in Makanya.

I. Context

Problem Framing Statement



Private clinics and dispensaries do not have access to accurate anemia testing devices and must rely solely on clinical diagnosis by the naked eye. We aim to develop a smartphone application that assists medical practitioners in diagnosing anemia by checking for pallor in the conjunctiva, which is a sign of anemia.

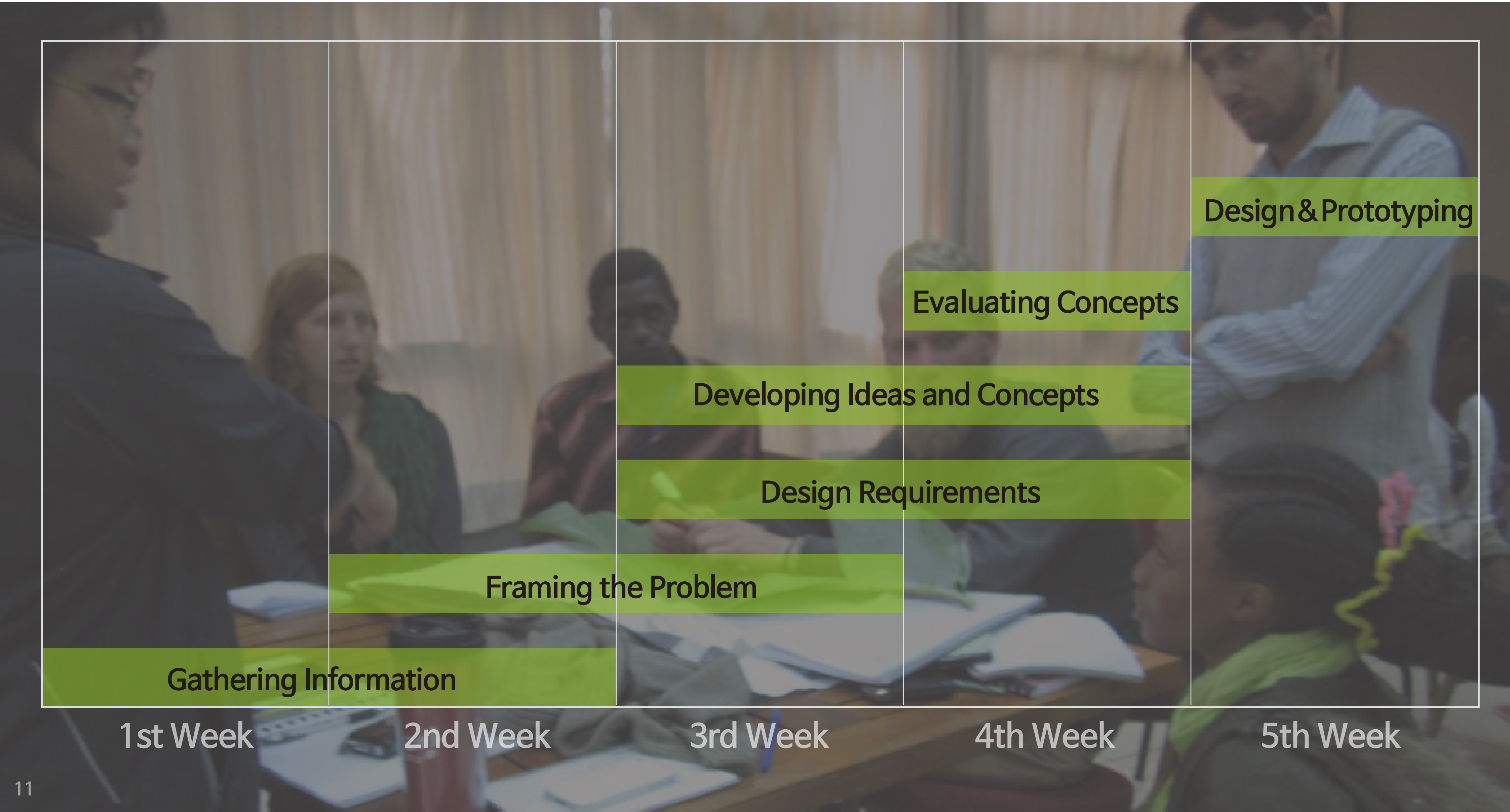


II. Design Process

Process Overview
Gathering Information
Framing the Problem
Idea Generation
Concept Evaluation

II. Design Process

Process Overview



II. Design Process

Gathering Information

Before our first community visit, we started information gathering by various methods. Our team went through secondary research and stakeholder analysis to have general knowlege about the topic and to prepare user interview. During the first community visit, which was three days, our team did interviews with potential stakeholders, and observe, ask, try in order to gather information broadly within the topic.

Secondary Research

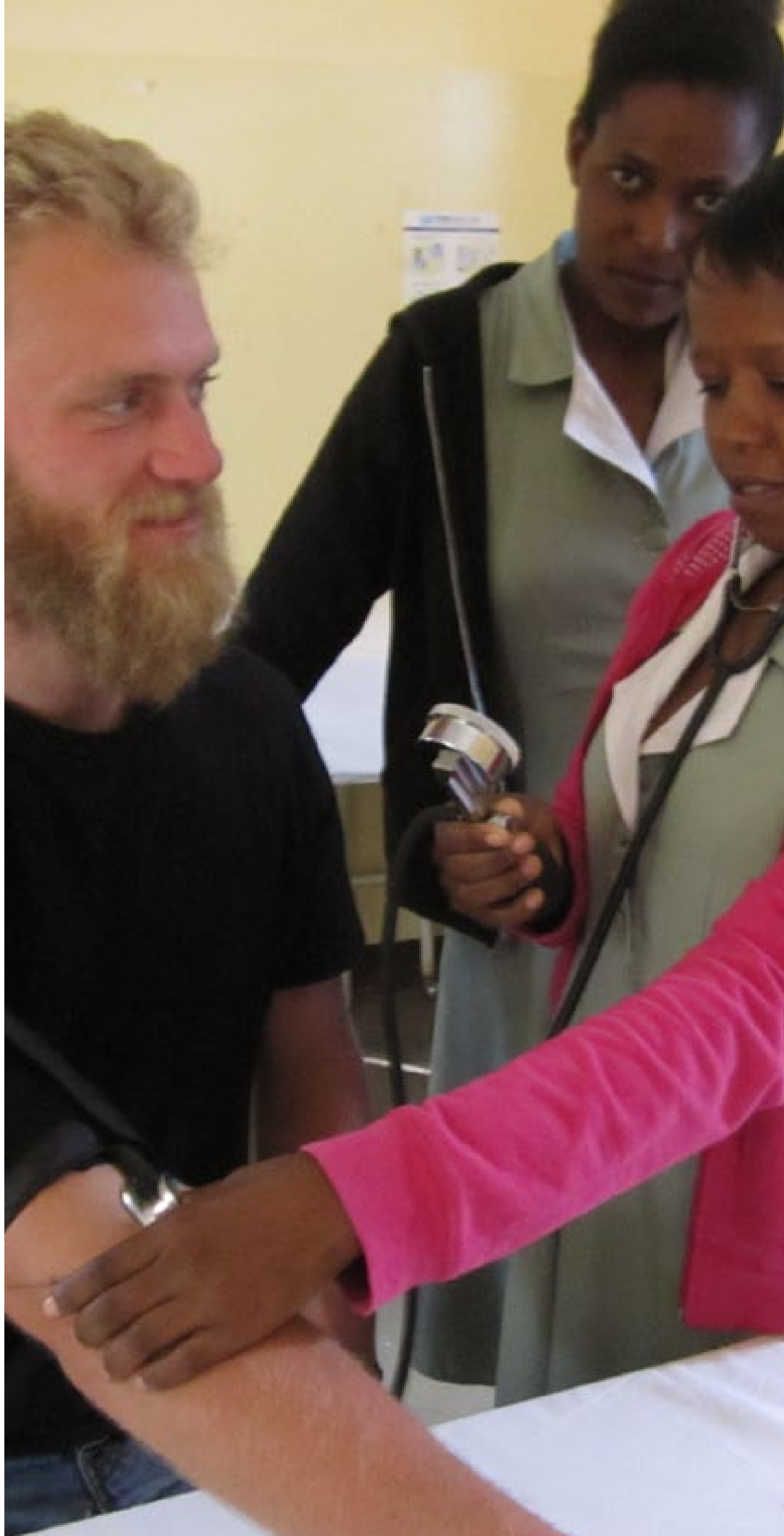
We did genearl reserach on our topic, maternal health. We could find many resources of on-going projects on our topic, and main health problem in Tanzania.

Stakeholder Interview

During our visit, we were able to meet local health officer and medical workers in public dispensary, and health clinic. We could build connections with these people and contact them afterwards to get more information. From our initial ideas about problem framing, we could get feedback in community meeting which help us to determine our next direction.

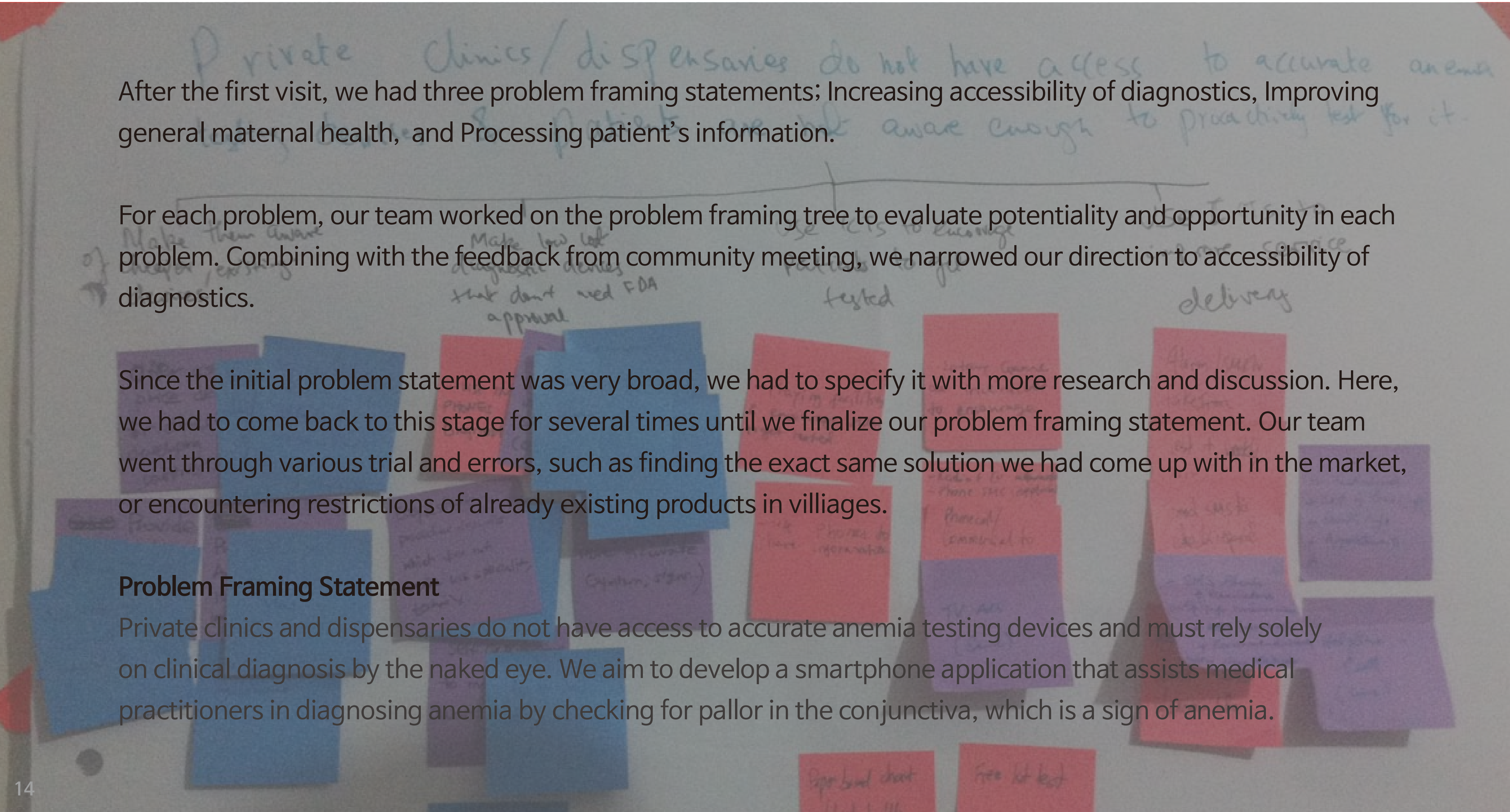
Observe, Ask, Try

All the team members were engaged in Observe, Ask, and Try methodology throughout our visit. When we visited medical related facilities, or interviewed mothers or family who have experienced giving birth, we divided into small groups to conduct different roles and discussed afterwards.



II. Design Process

Framing the Problem



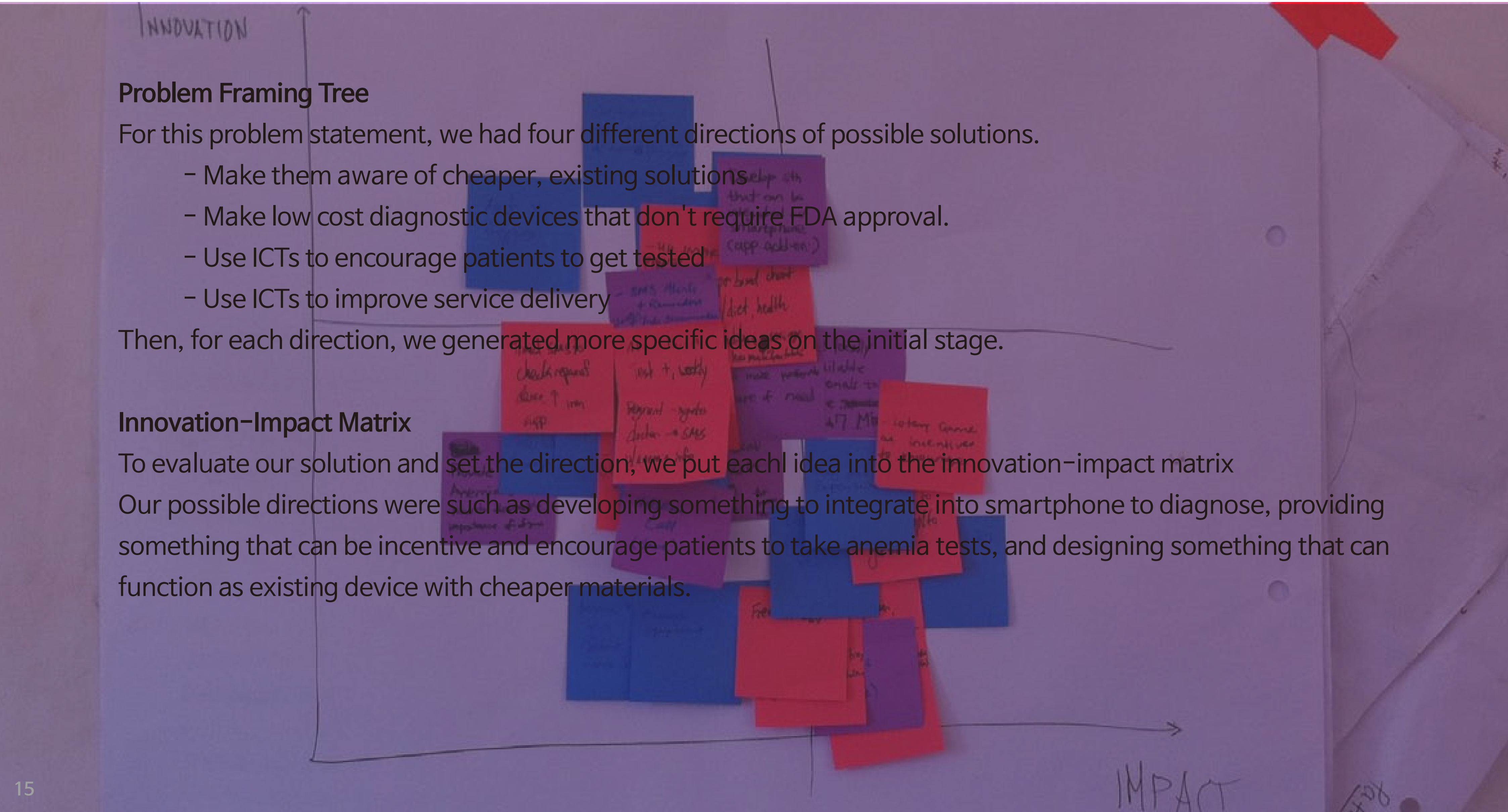
After the first visit, we had three problem framing statements; Increasing accessibility of diagnostics, Improving general maternal health, and Processing patient's information.

For each problem, our team worked on the problem framing tree to evaluate potentiality and opportunity in each problem. Combining with the feedback from community meeting, we narrowed our direction to accessibility of diagnostics.

Since the initial problem statement was very broad, we had to specify it with more research and discussion. Here, we had to come back to this stage for several times until we finalize our problem framing statement. Our team went through various trial and errors, such as finding the exact same solution we had come up with in the market, or encountering restrictions of already existing products in villiages.

Problem Framing Statement

Private clinics and dispensaries do not have access to accurate anemia testing devices and must rely solely on clinical diagnosis by the naked eye. We aim to develop a smartphone application that assists medical practitioners in diagnosing anemia by checking for pallor in the conjunctiva, which is a sign of anemia.



Problem Framing Tree

For this problem statement, we had four different directions of possible solutions.

- Make them aware of cheaper, existing solutions
- Make low cost diagnostic devices that don't require FDA approval.
- Use ICTs to encourage patients to get tested
- Use ICTs to improve service delivery

Then, for each direction, we generated more specific ideas on the initial stage.

Innovation-Impact Matrix

To evaluate our solution and set the direction, we put eachl idea into the innovation-impact matrix
Our possible directions were such as developing something to integrate into smartphone to diagnose, providing something that can be incentive and encourage patients to take anemia tests, and designing something that can function as existing device with cheaper materials.

II. Design Process

Idea Generation

Next steps after settling on direction were generating ideas and determining the design requirements.

Design Requirements

Based on information gathering and discussion, the design requirements were as below;

- Affordability
- Accuracy/ Precision
- No need for additional training
- Not invasive
- Safety
- Reliability

To priortize each requirement, we asked medical-related workers to give us their opinion.

Brainstorming

Our team went through two brainstorming sessions. At first, everyone had an hour to freely generate ideas. Then, we put all of ideas on the wall and review each idea together to build new ideas based on them.

Concept Development

After brainstorming session, it was possible to see the focus of our interests which had more frequency of discussion and more developed than other ideas.

III. Design & Prototyping

Design Idea
How it works
Prototyping
- Smartphone Application
- Standardzation of Light
Anticipated Performance

III. Design & Prototyping

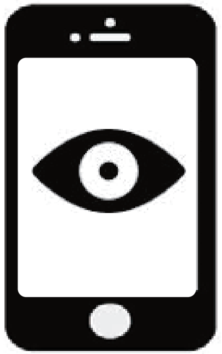
Design Idea

Not invasive method

Redness $\propto$ Hb Level

Conjunctiva Diagnosis

Affordable/ Accessible



Smartphone Application

For our final design idea, we focused on two main design requirements “Non Invasive” and “Affordable/ Accessbile.” We developed ideas on how to improve clinical diagnosis, and among several options we worked on conjuntiva diagnosis. Since redness of conjuntiva is correlates to hemoglobin level, it is possible to make clinical diagnosis more accurate. To make this diagnozing tool more affordable and accessible, embedding this in smartphone application.

III. Design & Prototyping

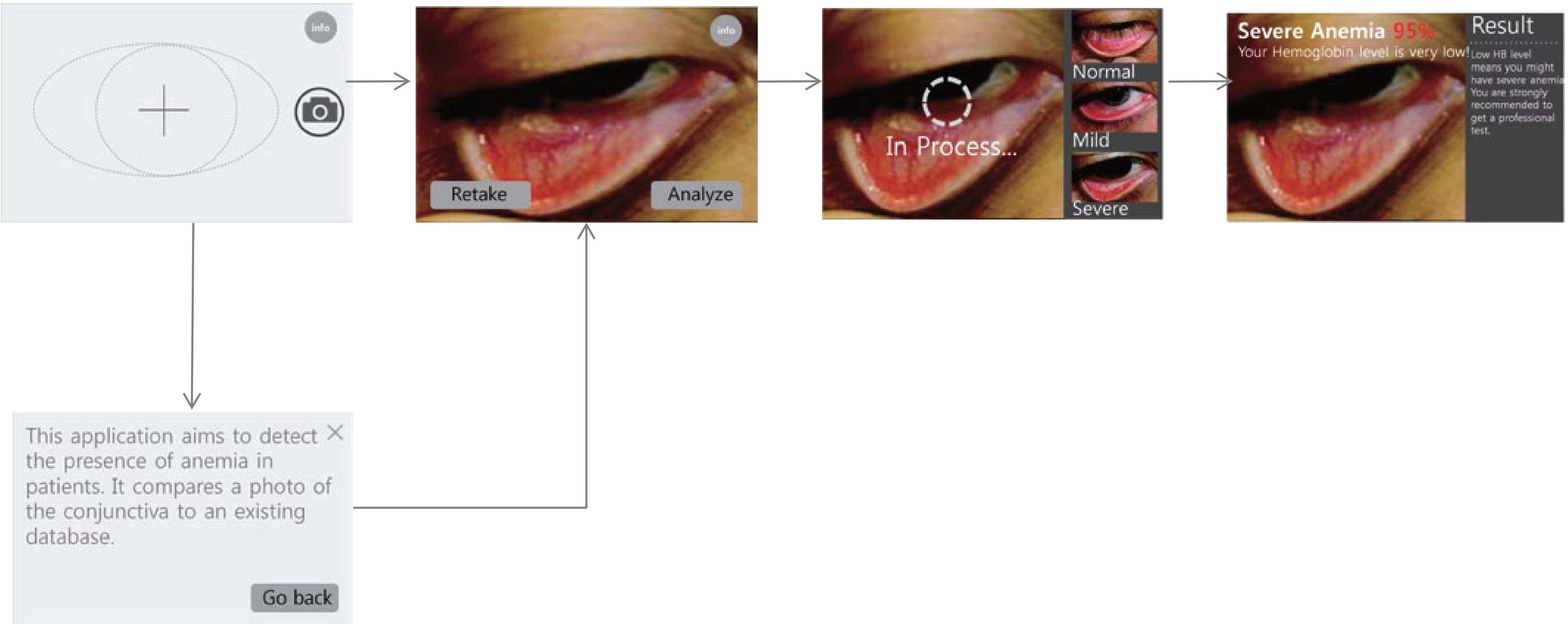
How it Works

1 Take a photo

2 Calculate amount of Red

3 Diagnose Probable Stages

This application works in very simple way to minimize additional training of users. The user interface and flow are similar to other camera applications. At first, user can take picture of patient's conjuntiva with color chart. Using color chart, application go through image processing to analyze the redness of conjuntiva. Then, by the calculated value of redness, it diagnose probable stages and suggest the recommended action afterwards. Refer to the next page for example of user flow in this application.

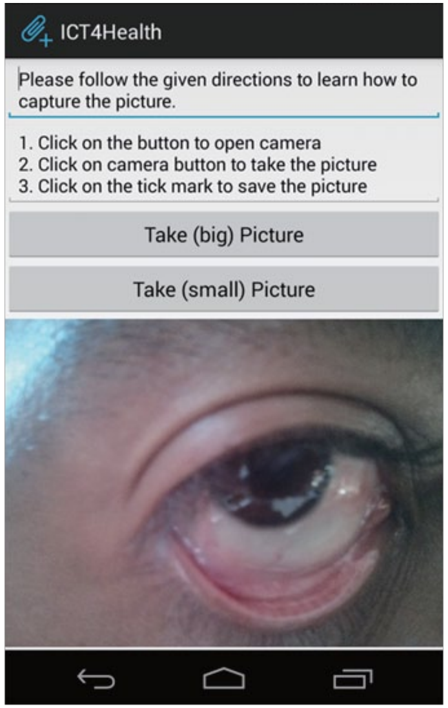


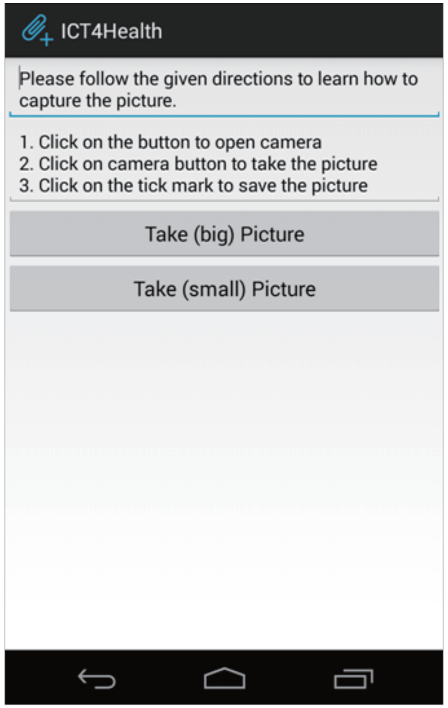
〈Example of User Flow〉

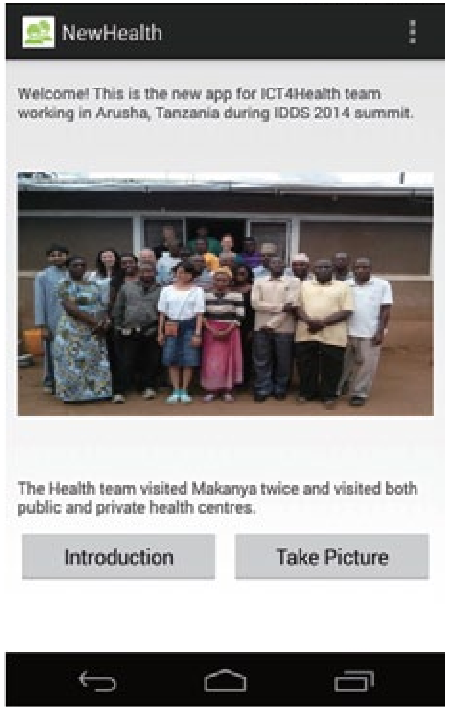
Prototyping

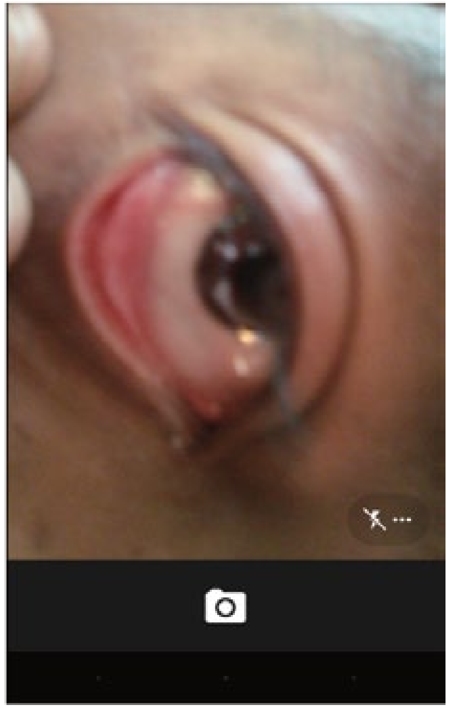
Our main challenges within this design were developing working application on smartphone and standardazing each photo taken. Since we had two team members and design facilitator who are expertized in programming and developing application, we managed to develop an initial version of our design to show basic functions. To simplify image processing, standardazation of light condition and size of conjuntiva was another challenge. We tried to make add-on to smartphone to generalize the condition with different materials and design.

Smartphone Application









These are screenshots of the current status of the phone application. Functions include taking saving, and viewing an image. It also supports zoom, which is essential in obtaining a large enough image.

Standardzation of Light

Our main focus was making add-on for smartphone with D.I.Y(Do It Yourself) concept. So it will be available to any users with low cost materials. Materials we used include cardboard box, paper, rubber band, clay, silicon, and plastic cups.

Anticipated Performance

Silicon // Paper cone is attached in front of the phone's lens using a rubber band. The cone insures even lighting and reduces highlights, hard shadows and movement of image. The patient is asked to pull down the skin under one eye, so that conjunctiva becomes visible. Cone is then placed over the eye with the conjunctiva visible. The app activates the camera, scans the image and adjust zoom and focus automatically, so that a focused image of the conjunctiva can be obtained. After the picture was taken the cone can be removed. The picture has then to be cropped manually by user (not by patient), so that only an out-take of the conjunctiva is visible. The app scans the picture, analyzes the RGB value of each pixel and calculates general redness of the image. Based on a correlation value obtained from prior research severity of anemia is diagnosed.

IV. Design Evaluation

Alternative Technologies

Selection Matrix

Self-Assessment

IV. Design Evaluation

Alternative Technologies

Several alternative technologies to diagnose anemia exist in various stages, some of which are available in health facilities around Makanya.

HemoCue / Mission plus / Blood analysis

HemoCue and Mission+ both assess Hemoglobin levels using a small blood sample. The Hemocue uses a small glass slide called a Cuvette. A drop of blood is put on the slide, which is then entered into the Hemocue. On the cuvette te blood mixes with dried reagents, hemoglobin is assessed using an modified azide-methemoglobin reaction. Cuvettes can only be used once. The HemoCue itself costs about 500$, cuvettes cost approximately 1$ per cuvette. The HemoCue is purchased and distributed by the district of Same, and present at most public health facilities we visited. Cuvettes have to be ordered by the respective health facility. They are distributed free of cost for the facility, but are often not available to facilities and patients, due the relatively high price of each cuvette. The high price of the device itself makes it very difficult to purchase for private health facilities. Hence, we were unable to find it in any private health facility, whose self-reported available budget for anemia-testing devices lies between 15 and 40$.

An alternative, cheaper device is the Mission+. Mission + also uses a blood sample, which is dropped on a small strip of paper. The strip is entered into the Mission+, which analyzes the amount of Hemoglobin per liter modified azide-methemoglobin reaction technology. The Mission+ does not seem to be readily available since we only encountered it at one health facility. The price is unknown to us. The strips are significantly cheaper than the cuvettes needed for the HemoCue, which made the Mission+ the preferred device at the health facility that had access to it. Strips can also only be used once.

While both devices accurately and reliably assess hemoglobin levels they are both invasive methods, which increase the risk of infection. Furthermore, both technologies come with recurring costs, as the required cuvettes or strips can be used only once and have to be purchased at relatively high price. Necessity of strips and cuvettes also makes these technologies vulnerable to shortages. Tests cannot be administered if the government fails to deliver cuvettes or strips to the respective facilities.

Spectroscopy

Spectroscopy is a technology that shines light of specific wavelengths on (reflectance spectroscopy) or through (transmissive spectroscopy) a surface and measures the wavelengths of the reflected light. By analyzing the absorbed wavelengths one can conclude on the presence of certain particles in the blood. A common technology based on spectroscopy is pulse oximetry. A pulse oximeter shines light of two wavelengths through the fingertip of the ring finger on the non-dominant hand. A photodiode measures the wavelengths of the light passing through the finger. Absorbance of certain wavelengths indicates the oxygen saturation rate of the available hemoglobin.

Several devices have built on this technology, such as the OrSense or the Pronto 7. These devices use light of different wavelengths to not only assess the oxygen saturation of the available hemoglobin, but the hemoglobin saturation of the blood, which allows these devices to be used to diagnose anemia precisely and reliably. The technology is relatively new, with devices having been available for about 10-15 years.

Spectroscopy seems to be the preferable method to accurately assess Hemoglobin per liter, as it is non-invasive and does not come with recurring costs. Nevertheless we were not able to find it in any health facility. The price makes it difficult to purchase for private health facilities. Furthermore, spectroscopy is influenced by melanin. Its accuracy varies depending on skin color of the patient.

Clinical diagnosis

The lack of healthy red blood cells in anemia changes the color of the blood. This can be observed as pallor in a patients palpebral conjunctiva (inner eye lid), the palms of the hand and nail beds. Assessing pallor of palms, nails and conjunctiva requires training and experience. Different studies found different results, but its accuracy seems to be limited to distinguishing between 3-4 levels of anemia. A similar method is used to diagnose anemia in cattle and sheep. Here, pallor of an animal’s conjunctiva is compare with a color chart. Several studies have shown that this method to reliably distinguish between 5 levels of anemia. Clinical diagnosis in humans seems to be limited to the assessment by trained individuals using naked eye sight, no assisting technologies seem to be available. Two MIT D-Lab classes attempted to change this by using spectrophotometry to measure redness in a patients conjunctiva (the conjunctiva is the preferred location to assess pallor due to the absence of melanin). Spectrophotometry shines light of different wavelengths on a surface. The color of the surface can be determined by measuring the wavelengths of the reflected light. The devices have never left prototyping stage.

We tried to develop a similar technology, and started prototyping using and Arduino and a Pulse Oximeter. We managed to record light intensity using the Arduino, but were not able to determine what wavelengths are needed to detect hemoglobin. Additionally the level of affordability private health centers in rural areas mentioned was so low that developing a new device did not seem useful, as health practitioners would be unable to pay for it.

We decided to use smartphones and image processing to assist in accurately assessing the color of a patients' conjunctiva. We chose this route as smartphone technology is already available and used by the health care professionals we spoke to, which reduces the need to purchase a new device.

Furthermore the presence of smartphones will rise over the next few years. The technology is non-invasive, excludes recurring costs and is easy to use so that it requires no additional training. The biggest disadvantage is its limited accuracy. The redness of the conjunctiva is used as a proxy to determine the quantity of hemoglobin. Assessing hemoglobin levels directly is obviously more accurate.

Gold Standard: Complete Blood Count

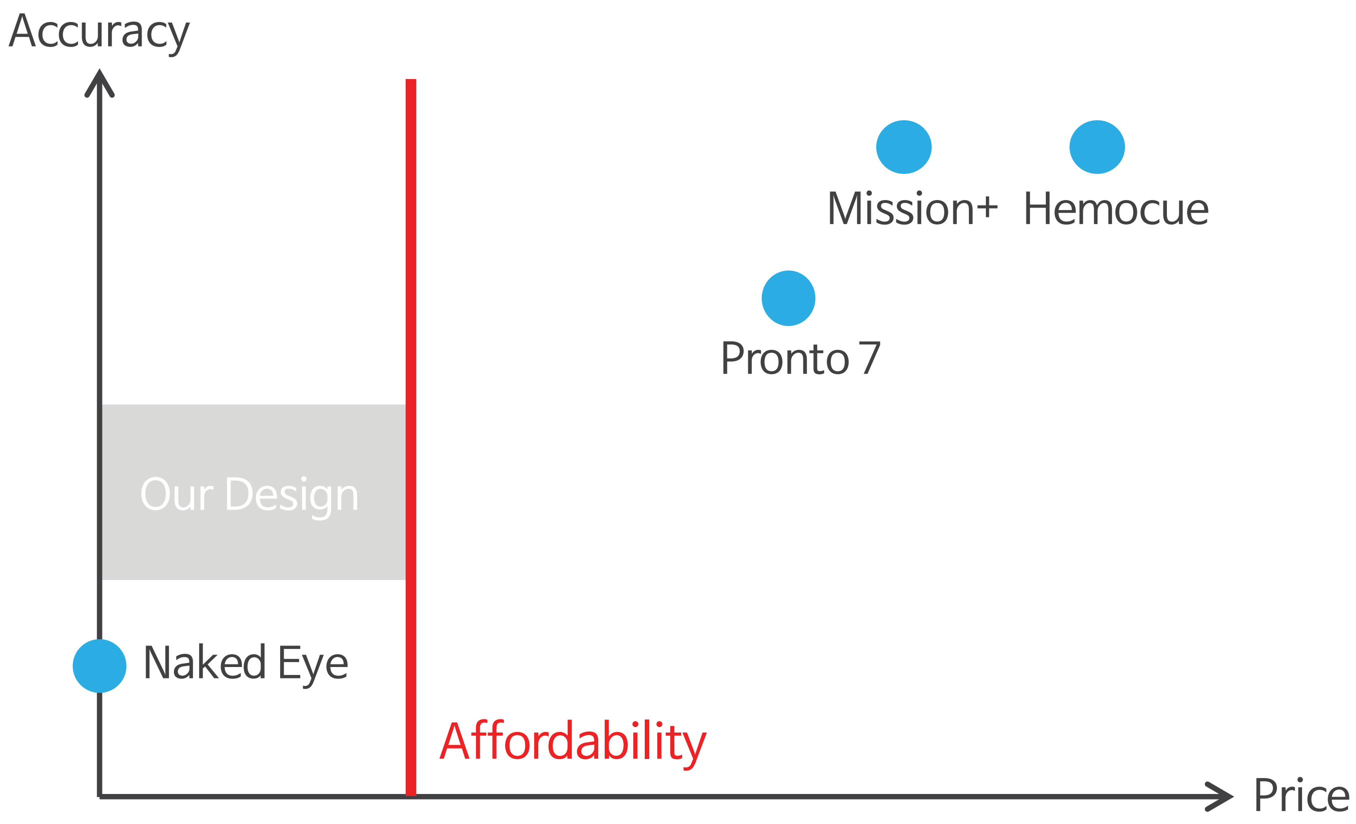
The gold standard of anemia diagnosis is a complete blood count. This procedure requires a bigger blood sample and - more importantly - an automated hematology analyzer. It results in a complete analysis of the blood, including a count of red blood cells, white blood cells, hemoglobin levels, hematocrit, mean corpuscular volume of the blood cells, mean corpuscular hemoglobin, and more. All of these tests pose valuable additional information for the diagnosis of anemia.

IV. Design Evaluation

Selection Matrix

Criteria	Baseline: NakedEye	HemoCue	Pronto7	MIT / Reflective Spectrophotometry	Mission+	App	CBC
Reusability/recurring costs	0	-2	0	0	-1	0	-3
Affordability	0	-3	-2	-1	-2	0	-3
Accuracy/Precision	0	+2	+2	+1	+2	+1	+3
Reliability	0	+2	+2	+1	+2	+1	+3
Safety	0	-1	0	0	-1	0	-2
Ease of use	0	+1	+2	+1	+1	+2	-2
TOTAL	**0**	**-1**	**+4**	**+2**	**+3**	**+4**	**0**

Based on our design requirments, we defined criteria to evaluate each technologies using matrix. To compare these alternatives with our design following the most important criteria, accuracy and affordability, we positioned each alternative on the quadrant.



〈Accuracy Vs. Affordability〉

IV. Design Evaluation

Self-Assessment

Financial

The software for the smartphone is free and will be available in the Google Play store. We eliminate the recurring costs of the currently used devices. Our application thereby makes anemia testing affordable to literally everyone.

Technical

The solution relies on smartphone technology, which is not available to everyone. Nevertheless, smartphones are available in Tanzania starting at approximately 40$, and most health care practitioners we interacted with used one. Over the next month and years the use of smartphones in rural areas of Tanzania will rise, making our technology more accessible. We plan to release the software open source, which means the code it is made of is accessible, and developers can build on top of our solution, add functions, improve and adjust it to their specific needs.

Environmental

While the application itself has minimal impact on the environment, the required smartphones make up for a large part of the growing amount of e-waste worldwide. Informal recycling of electronic devices poses dangers for water, soil and air.

V. Continuity

Reflection on viability and other design opportunities

6-month plan and team engagement

Anticipated risks and challenges

V. Continuity

Reflection on Viability & Other Design Opportunities

The viability of our product is to be determined, as its effectiveness is still difficult to measure. The application will definitely not act as a replacement for a laboratory test that can quantitatively measure hemoglobin levels in blood. Rather, it is a tool to more accurately clinically diagnose anemia. If the test is able to more accurately determine the level of conjunctiva pallor than the naked eye, it could increase the amount of individuals who are treated for anemia.

As briefly mentioned, there are several other technologies available, some of which pose alternative design opportunities to make anemia testing more affordable, since most of these technologies are not available in the communities we visited. These include Spectroscopy and building a device using this technology, similar to the OrSense or the Pronto 7.

A more feasible technological alternative technology is spectrophotometry. A device using this technology could possibly measure redness in the conjunctiva more accurately. The costs associated could possibly be lower than the current cost of a smartphone, since it mostly consists of a LED, a photodiode and a screen. As mentioned in the Technology section of this report two MIT D-Lab classes worked on this technology, but did not develop a market-ready device.

The viability of our application as well as the spectrophotometry solution both depend on the strength of the correlation between redness of the conjunctiva and hemoglobin levels. The relationship needs to be investigated in a clinical trial, which is one of the first steps of continuing this project.

Several studies show that such a relationship exists, of varying degrees of strength, in both humans and animals such as sheep and goats. To our knowledge none of these studies uses technology to assess redness, but instead rely on the trained eyes of health practitioners. Such a study would therefore not only help us build a useful technology but also advance science.

Before such a study can be carried out, we need to develop a satisfying way to standardize the image in terms of light and color while it is taken. We have built several prototypes, consisting of devices that cover the eye and camera to keep out light, and use the flashlight of the phone, or reduce shadows and highlights of the available light. However, none of the prototypes achieved satisfying results, as the flash created too many highlights, and available light still influenced the amount of light in the picture.

Next steps therefore consist of the following:

1. Develop standardized lighting
2. Conduct study to investigate relationship between ratings of conjunctiva redness and hemoglobin levels

V. Continuity

6 Month Plan
& Team Engagement

All 6 team members expressed strong interest in continuing the project. At this point in time, ca. 4 weeks after IDDS we agreed to speak weekly via Skype. We have not divided roles for the next 6 months, but divide tasks based on immediate next steps. The weekly call serves to report results and plan next steps. We use Google Drive and Dropbox to share files and results of research individual members do. We do not have a detailed 6 month plan yet. The current next steps include further research into the science of anemia diagnosis, clinical diagnosis and the relationship between hemoglobin levels and conjunctiva pallor. As mentioned above we also work on the technical side of the application. We try to develop a method to standardize lighting and colors before taking the image, and test various ways to measure color in a digital image.

V. Continuity

Anticipated Risks & Challenges

Empirical evidence of the relationship between conjunctival pallor and hemoglobin levels is mixed. This means that a more thour-ough assessment of pallor using smartphone cameras and image processing technology might not result in a more accurate diag-nosis of anemia than diagnosis by naked eye.

To gain clarity about the value of the proposed technology a clini-cal study of the correlation between RGB values of an image of the conjunctiva and hemoglobin levels of the same person is neces-sary. This study seems like a challenge at the moment, as a) the technology is not developed enough and b) we do not know yet how to even start such a clinical study.

Another challenge might be time and resources available. Since most of us are involved in other time-costing activities (such as work) the time available to spend on the Anemia project is limited.