Using Digital Product Design to support Medical Staff during Cervical Cancer Screenings in Low Resource Settings

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28 / 07 / 2024

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Acknowledgement

I would like to convey my most heartfelt appreciation and indebtedness to the following individuals, for without their invaluable contributions this thesis would not have been made possible.

My sincere thanks to JC and Magda, my chair and mentor, for their invaluable guidance and feedback. With your assistance, I was able to find a clear direction for the project and I learned how to best articulate matters towards the client.

I am deeply grateful to Dr. Conrad Tankou, lead at GICMED (GIC Space), for his hospitality and indispensable support during my two-week stay in Cameroon. Your efforts and vast network, allowed me to visit various hospitals, get a peek behind the scenes and engage with the medical professionals there. Furthermore, I am grateful for your trust in me and for the privilege of working with your company.

I would like to express my great appreciation for Dzekewong Karlson Fonyuy, who took the time to review my concepts and share suggestions. Your thoughts and feedback have been incredibly helpful in enhancing my redesign of the GICMED application.

Big thank you to Karlheinz Tondo Samenjo for your support, for devoting your time to enrich me with your knowledge in the field and for letting me get acquainted with the culture, food and customs in Cameroon. It was truly an amazing experience!

I wish to thank Sem Blessing for your company and invaluable assistance in Cameroon. I am grateful for the time and effort you invested in translating my interview questions into French, and for your support during the interviews.

Many thanks to Marijke Spijk and Mirthe Hofstede for taking me through the project from the very beginning and for all your insights and updates on your own progress, as it was crucial for the developments in mine.

And lastly, I wish to thank the AED students of the master IPD for the enlightening meetings and crucial agreements we made to steer our projects in the right direction.

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Glossary

Term	Definition
AED	Advanced Embodiment Design
AI	Artificial Intelligence
CBC	Cameroon Baptist Convention Health Services
CCS	Cervical Cancer Screenings
GIC Space	Global Innovation and Creative Space
GPs	General practitioners
DAMA	Data Manager Software System
EHR	Electronic Health Record
EMR	Electronic Medical Record
HIV	Human Immunodeficiency Virus
LEEP	Loop Electrosurgical Excision Procedure
LRS	Low Resource Settings
MOH	Ministry of Public Health
MVP	Minimum Viable Product
PAP	Papanicolaou
STD	Sexually Transmittable Disease
VIA	Visual Inspection with Acetic Acid
VILI	Visual Inspection with Lugol's Iodine
WHO	World Health Organisation

Figure 1: A CBC hospital in Cameroon

Executive Summary

Cervical cancer poses a huge challenge to global health (Sung et al., 2021). To provide access to cervical-cancer care to women in Low Resource Settings (LRS), the startup GIC Space is developing the C-Spec and GICMED application. With these innovations the company aims to offer remote Cervical Cancer Screening (CCS) and diagnosis, and a more comfortable experience than with a regular speculum. With the implementation of Artificial Intelligence (AI) algorithms, diagnoses will partly be automated and this requires a new workflow for the app.

Literature revealed that the deployment of information systems (such as smartphones) is needed to offer professional support to medical personnel in LRS in performing and managing CCS. The objective of this master thesis was to redesign the existing GICMED application to enhance the interaction between patient and healthcare provider, and assist in keeping track of patient data more efficiently. GIC Space set the challenge to design for both highly trained medical professionals, like general practitioners and gynaecologists, and less trained healthcare providers such as nurses and midwives. By responding to medical practitioners' lack of expertise and experience to accurately diagnose cervical cancer, the GICMED application could increase screening reliability in LRS. In addition, allowing healthcare providers to have more time for patients, will enable them to better empathise with their client and will lead to better care.

The usability of the current application was inspected with a cognitive walkthrough. Insights about desirable features were gathered by means of a benchmark with competitors. Four User Journey Maps were created to explore design opportunities. To determine whether the concept would be viable, the Lean Startup Model was deployed to rapidly develop a Minimum Viable Product (MVP). The MVP was assessed through user testing in order to determine its desirability.

Since the redesign combines paper work and implements EMRs, patient data can be stored and accessed digitally, allowing personnel to work in a efficient manner and devote more time on providing care. EMRs enable exchange of patient data between healthcare facilities, which is particularly beneficial for reducing loss of follow-up. In order to establish an accurate diagnosis and management plan, AI should solely serve as a second opinion and still rely on the user's own judgement. To avoid AI’s diagnosis from simply being adopted, users should be requested to share their findings and diagnosis first, before AI hands over its conclusion.

During user tests, the redesigned application received an average score of 82.8 out of 100. Participants unanimously agreed that the app helps healthcare providers to keep track of patient data more efficiently and two out of three subjects agreed the app allows both user groups to devote more attention to patients and to express empathy.

This master thesis highlights that potential users are open to trust the result given by AI. Users will first provide their own judgment and then utilise AI’s findings to come to a final conclusion. This thesis thereby affirms the potential for the integration of AI to partly automate diagnosis for cervical cancer.

1. INTRODUCTION

Background information regarding Cervical Cancer Screenings, the C-Spec and the supplementary app is provided. The project approach is explained by going into the initiation of the project and how this MSc thesis was carried out.

1.1 Background information

1.1.1 Cervical Cancer Screenings

Cervical cancer poses a huge challenge to global health, ranking as the fourth most prevalent cancer affecting women worldwide (Sung et al., 2021). Its impact is particularly devastating in developing nations, where it is the leading cause of cancer-related deaths. Approximately half of the 660 000 new cases in 2022 resulted in death in low- and middle-income countries (WHO, 2024). Although, if identified at an early stage and promptly intervened with treatment of precancerous lesions, the risk of long-term complications can be significantly reduced (Mishra et al., 2011). These measures also play a crucial role in limiting further transmission from mother to child, thus ensuring the welfare of both current and future generations (Peeling & Mabey, 2010).

The conventional approach to Cervical Cancer Screenings (CCS) involves a PAP (Papanicolaou) test followed by a colposcopy. However, the high cost and specialised training required for colposcopes make them less attainable in Low Resource Settings (LRS) (Bruggen, 2024). As an alternative, the World Health Organization (WHO) used to suggest Visual Inspection with Acetic Acid (VIA) as a cost-effective option (WHO, 2021). However, the subjective interpretation of VIA, the provision of less magnified images and potential for over-treatment pose concerns (Mueller et al., 2017). In contrast, HPV-DNA testing has been proven highly effective in reducing cervical cancer deaths. Although this method is more sensitive and more cost effective compared to other CCS tests, its present costs, the need of high level staff and multi-visit approach hinders implementation in LRS (Defo & Domgue, 2020).

A massive challenge in women's healthcare in LRS is the lack of access to medical care (Nour, 2008). Although this is not an issue exclusive to women, women are typically the ones who bear the brunt in medically underserved populations due to limited control over their own lives (Okojie, 1994). It is, therefore, crucial to increase efforts to ensure that women in LRS can access care. Opportunities that are already being addressed in Cameroon are: educating communities about the importance of CCS and lowering financial barriers. However, there are limited possibilities to offer professional support and mentoring to healthcare providers to deliver quality care (WHO, 2012).

Since utilisation of preventive health services is relatively low in LRS and personnel and resources are limited, CCS can be a challenge (Huchko et al., 2018). Furthermore, there is a severe shortage of facilities that can provide treatment for cervical cancer. Even in instances where surgical procedures and other medical care are accessible, families are at high risk of spiraling into debt and exacerbated poverty. This is due to the financial burdens resulting from treatment costs and the loss of work (Meara & Greenberg, 2015). Large-scale and swiftly implemented health campaigns emerge as a powerful approach to provide crucial healthcare interventions (Kahn et al., 2011). In Kenya, health campaigns even proved to be a more effective way to reach women than CCS in health clinics (Huchko et al., 2018). Given the upscaling to population-based screening, the adaptation of information systems become a necessity to manage coverage of high-risk individuals, plan screenings for follow-up and avoid unnecessary testing (Randall & Ghebre, 2016).

Figure 2: A women's health treatment room at a CBC hospital

1.1.2 The C-Spec & GICMED Application

This thesis builds upon the graduation projects of Femke Bruggen, Mirthe Hofstede and Marijke Spijk, and the development of the C-Spec by GIC Space (Global Innovation and Creative Space). GIC Space is a startup based in Cameroon and is dedicated to serving women in LRS. Through the company's flagship product GICMED, GIC Space aims to provide access to breast- and cervical-cancer care to women in sub-Saharan Africa (GICMED, n.d.).

At the moment, GIC Space is developing an affordable, partly automated colposcope variant. This medical innovation is called the C-Spec and is also referred to as the Smart Speculum. This device serves as both a speculum and a colposcope, offering enhanced visibility of the cervix without the hefty price tag associated with conventional colposcopes. The word 'Smart' in Smart Speculum refers to Artificial Intelligence (AI), which will partly automate diagnoses. The Smart Speculum is being developed to make CCS in LRS more accessible and is accompanied by a mobile app tailored for such settings. The current prototype of the C-Spec integrates a speculum with a camera and makes use of a smartphone with an app for viewing and capturing images (Figure 3).

Figure 3: Simulation of how the Smart Speculum will be used

Since most health workers do not have enough knowledge and experience to accurately diagnose cervical cancer, this innovation could improve screening reliability.

Key takeaways:

- It is of vital importance to identify precancerous lesions at an early stage and promptly intervene with treatment (Mishra et al., 2011).

- There are limited possibilities to offer professional support and mentoring to healthcare providers to deliver quality care (WHO, 2012).

- The adaptation of information systems becomes a necessity to manage coverage of high-risk individuals, plan screenings for follow-up and avoid unnecessary testing (Randall & Ghebre, 2016).

- By responding to medical practitioners' lack of expertise and experience to accurately diagnose cervical cancer, the Smart Speculum and GICMED application could increase screening reliability in LRS.

1.2
Project Approach

This chapter addresses how this graduation project was conducted and which research and design methods were adopted to generate the design solution.

1.2.1 Problem Definition

Due to limited opportunities to offer professional support and mentoring to healthcare providers, medical devices are often imported and being inappropriately and/or inadequately used. The repercussions of this incorrect usage can lead to adverse health outcomes and potential cost implications (WHO, 2012).

The word 'Smart' in Smart Speculum refers to AI, which will partly automate diagnoses. This implies a certain workflow for the app where digital diagnosis will be supported by AI, allowing it to be used by both highly trained medical professionals, like general practitioners (GPs) and gynaecologists, and less trained healthcare providers such as nurses and midwives (see chapter 2.1.1 for more information). Additionally, the app can help healthcare providers to keep track of patient data more efficiently, and could be used to notify patients who need to be reminded about follow-up as well as to stimulate women to undergo treatment.

1.2.2 Project Scope

A total of three graduating students from the faculty of Industrial Design Engineering, Delft University of Technology, the Netherlands, including two AED (Advanced Embodiment Design) student teams from the master Integrated Product Design, were put on the project by GIC Space. Whereas the AED students and Mirthe Hofstede primarily cover the user ergonomics and performance of the C-Spec, the focus for this thesis is on the redesign of the GICMED application (Figure 4). Although some

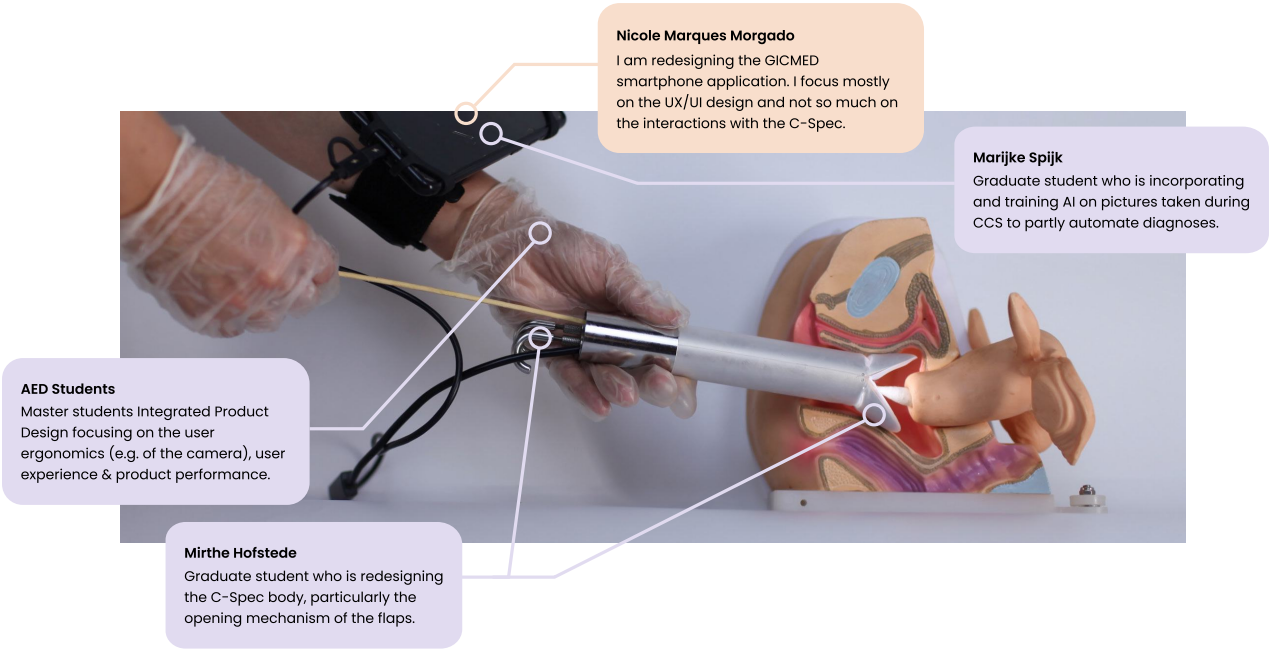


Figure 4: The project focus of everyone involved (photo from: Bruggen, 2024)

consideration was included as to how the future interaction with the Smart Speculum might look like (see chapter 2.1.3), the design of the wristband and phone holder are left out of scope, due to the limited time given for this project.

Marijke Spijk is addressing how AI could be incorporated to partly automate diagnoses and is training algorithms only on photos of cervices on which VIA was performed. She explained it will take a substantial amount of time to maximise the sensitivity and thus reliability of the AI algorithms. Hence, all other possibilities for AI outputs, which the app could display in the future, will have to be considered.

1.2.3 Methodology

The aim of this MSc thesis is to contribute to GIC Space's knowledge of their users and digital product, and will provide them with a deeper comprehension of the (digital) interactions that could improve the CCS procedure.

Methods and tools utilised

Making use of various meaningful methods and tools has helped to create new value for the stakeholders involved:

- User Journey Maps are focused on the goals, motivations and experiences of users, and can assist in improving the user experience. Four User Journey Maps were made to explore design opportunities.
- Acting out the interaction with the C-Spec and a smartphone helped to determine what would be the best way of interacting with the device and how the risk of contamination can be reduced.
- The usability of the current user interface of the GICMED app was inspected by means of a cognitive walkthrough to identify design criteria.
- Wireframes were deployed to visualise and understand the concept, and to get an idea of how the components will relate to each other.
- A benchmark with competitors provided insight into which well-conceived design features implemented in competing products are desirable for the redesign.
- A User Flow Diagram was made, to map the sequence of steps that have to be followed to accomplish a task or reach a goal within the app. Creating this diagram helped to understand how users will interact with the user interface.
- The Lean Startup Model was deployed to rapidly develop a Minimum Viable Product (MVP) and to determine whether the concept is viable.
- User Tests were conducted to uncover potential usability issues and to assess whether the high fidelity prototype would be desirable.

Figure 5: One of the district hospitals visited in Cameroon

Figure 6: Examination room of a general practitioner in a district hospital

Field Research

During the two-week stay in Cameroon, it was possible to observe three CCS, including 1 VIA/VILI (Visual Inspection with Lugol's Iodine) test and 2 HPV-DNA tests. Thanks to GIC Space, a variety of hospitals were visited where observations and qualitative interviews with medical staff could be conducted (see Figures 5 & 6).
A total of 24 participants have been interviewed, including:

- A Head Nurse (1)
- Nurses (8)
- Midwives (4)
- Gynaecologists (2)
- General Practitioners (3)
- Resident Doctors (4)
- Deputy Director for Clinical Services at CBC (1)
- Data Manager at CBC (1)

The majority of days in the field were spent at a CBC hospital in Yaoundé, the capital of Cameroon (see chapter 2.1.1).

The primary objective of the field research in Cameroon, was to gather information from healthcare professionals (such as nurses, midwives, gynaecologists and GPs) about the context and procedure of CCS in LRS, and to identify the challenges and opportunities related to CCS. Being there on site, also provided the opportunity to do observations, identify stakeholders, create a User Journey Map with experts in relevant fields and consult with specialists on desirable product qualities during an evaluation session of a competing product of the GICMED app.

1.2.4 Thesis Set-Up

This MSc thesis covers four essential stages in a design process: Research, Ideation, Conceptualisation and Evaluation, which serve as the foundation for the thesis's framework.

A general introduction to this thesis is provided through background information and a clarification of the project approach.

Chapter 2 introduces the key stakeholders and clarifies the exploration of GIC Space's current prototypes. Four User Journey Maps are discussed that were made to identify design opportunities and to formulate the assignment for this project.

Chapter 3 addresses the ideation phase, explaining the formation of an inspiration board to determine the look and feel of the redesign, a benchmark with competitors to understand which design features should be implemented, and the translation of ideas into a first set of wireframes.

Chapter 4 clarifies the manner in which the final wireframes were transformed into the final design, and the way the redesign is intended to be used.

Chapter 5 discusses how the final design was evaluated with potential users, the manner in which data was collected, and the analysis of the findings.

Lastly, chapter 6 provides recommendations for the further development of the application and a general conclusion whether the redesign actually meets the design goal set at the start of the project.

2. RESEARCH

This chapter provides information on desk research and field research carried out during this MSc project. The key stakeholders are introduced and the exploration of GIC Space's current prototypes is discussed. With insights gathered from the field, four User Journey Maps were created in order to identify design opportunities and formulate an assignment for the project.

Figure 7: The view from the street where GIC Space is based

2.1 Desk Research

This chapter introduces the most important parties involved in the project. It further addresses how GIC Space's current prototypes, of both the application and the device, have been explored by means of a cognitive walkthrough and by simulating the interaction between both products.

2.1.1 Stakeholders

There are many stakeholders involved in this MSc thesis project. Considering that the GICMED app was specifically designed for healthcare providers in LRS, the decision was made to redesign the app for these individuals.

Highly trained medical professionals

For this thesis, the challenge was set by GIC Space to design for two user groups working in LRS: highly trained medical professionals and less trained healthcare providers. These overarching names are based on the healthcare providers' knowledge of the entire cervical cancer procedure and the amount of experience they have in performing CCS to make an accurate diagnosis. Generally, the group of highly skilled medical professionals, including GPs and gynaecologists, has more experience and knowledge to provide an accurate diagnosis than the other user group.

Less trained healthcare providers

This user group consists of health workers, such as nurses and midwives, who have undergone a training in order to conduct CCS, but usually have less experience and knowledge, compared to the highly trained user group, to make accurate diagnoses.

The expertise of these individuals depends on where they received their training and how often screenings have been practised in the field. For some treatment methods such as thermal ablation, the WHO suggests that it may be practised by trained nurses, midwives or health care workers to guarantee the availability and accessibility of treatment (WHO, 2019). However, removing precancerous cells with LEEP (Loop Electrosurgical Excision Procedure) requires a certificate, of which there are only a few within this group that possess one (ACOG, n.d.).

This user group generally has to deal with a deficiency of diagnostic equipment and, according to Mbanga et al. (2019), depression is very common among nurses in English-speaking parts of Cameroon, which results in a significant decline in efficiency and productivity.

GIC Space

As mentioned in chapter 1.1.2, GIC Space is a startup that aims to provide access to cervical-cancer care to women in LRS. To realise this goal, the company is developing the C-Spec and GICMED app to offer remote screening and diagnosis and a more comfortable CCS experience than with a regular speculum (GICMED, n.d.).

There are two clients for this project: Dr. Conrad Tankou from GIC Space & PhD Candidate Karlheinz Samenjo (further called "Karl" in this thesis) who is closely involved with the startup and conducts research on their behalf. Dzekewong Karlson Fonyuy (further called "Karlson" in this thesis) is a Software Engineer working for GIC Space with whom frequent contact was maintained to obtain feedback on the design.

Women in LRS (Patients)

The patients receiving care by the mentioned user groups are women in LRS. According to the WHO (2021), women between the ages of 30 and 49 should be prioritised to be screened on cervical cancer, since the likelihood of contracting and dying from cervical cancer is higher among this age group.

Male partners have a substantial influence on women's healthcare choices and health-seeking behaviours in Cameroon. However, men lack basic understanding of cervical cancer, as they are insufficiently aware of this disease. Another challenge women in LRS face are financial constraints. The cost of CCS goes beyond the procedure itself, as women have to deal with lost wages for accessing care and increasing transport costs the further they live from healthcare facilities. Especially the distance from integrated health centers is a significant barrier for women living in rural areas to seek care, leading to disparity between rural and local areas (Roux et al., 2021). A multi-visit approach, where screening and treatment are not performed in a single visit, is therefore not desirable in LRS and often result in a major loss of follow-up (Defo & Domgue, 2020).

The Cameroon Baptist Convention Health Services

The Cameroon Baptist Convention Health Services (CBC), is a non-profit organisation inspired by Christianity that offers medical services to those in need. This hospital chain consists of 14 stationary clinics and several mobile clinics distributed all over the country. CBC intends to help Cameronians, especially the most deprived people in both rural and urban environments, in receiving quality care (Cameroon Baptist Convention Health Services, n.d.). The majority of days in the field were spent on conducting research in a Women's Health Department at a CBC facility.

Data Manager at CBC

Conducting research in the field, revealed that CBC employs Data Managers for entering patient information in computers and cross checking data for errors. In this particular hospital, each department makes use of the software EPI Info to fill in all information provided in the intake forms in this system. In the Women's Health Department, they are slowly transitioning to having nurses fill in the forms digitally with a digital colposcope.

Data Supervisor

According to the Data Manager at CBC, the intake forms used are designed by Data Supervisors. For each hospital department, there is one Supervisor nationwide who checks and manages all national data. If anything is filled in incorrectly, the Data Supervisor will contact the Data Manager for answers.

Other health facilities

The healthcare system in Cameroon is divided into three levels of care: Primary, Secondary and Tertiary care.

Primary care covers basic health services on a district level such as vaccinations, treatment of common illnesses and the supply of essential medicines. This type of care is offered by GPs and lower-level health workers in Integrated Health Centers, District Medical Centers and District Hospitals, see figure 8 (WHO, 2016).

Secondary care involves more expertise and is provided by doctors in District Hospitals and Regional Hospitals (such as CBC) at the regional level. Tertiary care is provided in Central Hospitals, General Hospitals and University Teaching Hospitals, and handles rare and complex disorders and hospitalisation. Along with the secondary level, they manage communicable diseases, non-communicable diseases, chronic diseases, accidents and violence (Ministry of Public Health, n.d.a; WHO, 2016).

At each of the three levels, the quality of services and care is insufficient according to the WHO (2016). This is for a number of reasons, including:

- Inadequate equipment and staff in technical facilities
- A lack of ongoing quality improvement (maintenance of materials, continuous trainings, etc.)
- Limited availability of essential drugs and supplies
- Reference/counter-reference systems are not practical

By addressing these issues, the C-Spec and complementary app could potentially be beneficial for all mentioned health facilities.

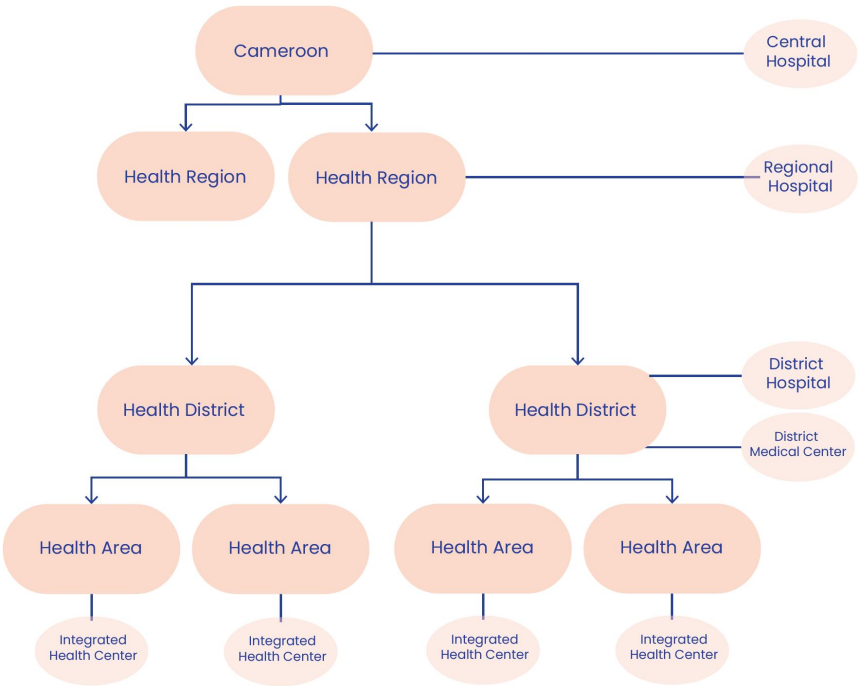


Figure 8: Healthcare levels and their corresponding facilities in Cameroon (Bruggen, 2024)

World Health Organization

The WHO's team consists of health specialists, like doctors, scientists and managers who use scientific evidence to coordinate the global response to health emergencies, prevent diseases, foster welfare and increase access to care. (WHO, n.d.b).

Considering the limited access to public health services and the deficiency of extensive screening and treatment for cervical cancer, the WHO devised a ambitious strategy to assist in the demise of the disease. Every country must meet the goal of attaining an incidence rate of less than 4 cases per 100,000 women by 2030. To reach this target, nations must attain a:

- 90% HPV vaccine coverage for girls by age 15
- 70% of women screened with a high-quality test by age 35 and once more before reaching the age of 45
- 90% of women with precancerous lesions and 90% with invasive cervical cancers treated

Fulfilling these three guidelines will make cervical cancer a preventable disease this century (WHO, n.d.a).

Ministry of Public Health

The Ministry of Public Health (MOH) in Cameroon is in charge of developing and implementing the government's public health policy. Among other roles, this means:

- Ensuring the organization, management and development of public health facilities
- Expanding healthcare coverage
- Ensuring the quality of care

By promoting health initiatives, like vaccines and family planning, the MOH strives to enhance the health and welfare of women and children (Ministry of Public Health, n.d.b).

The MOH is responsible for providing financial support to healthcare facilities. The portion of the state budget that was allocated to health, ranged from 3.5% to 5.9% (of which the MOH accounted for 95.5%) throughout a 10-year span (WHO, 2016).

Healthcare practitioners are obliged to keep track of patient data and to transmit all information to the MOH. A National Health Information System was therefore build to integrate data collection, processing and reporting. Possessing data on the performance of various facets of the health system can assist in making well-informed decisions and enhance healthcare services (Vukugah & Ndenkeh, 2022).

2.1.2 Usability Inspection

GIC Space is designing an application and desktop portal to support medical staff throughout the cervical cancer procedure; from performing the screening, to referring patients and processing information. This thesis specifically covers the user interface of the GICMED app (see Figure 9), of which the usability was inspected in this chapter.

Objective

The current user interface of the application was analysed on potential usability issues. This is especially useful in the beginning of the development process and can be done by conducting a cognitive walkthrough.

Method

The cognitive walkthrough is a in-depth inspection method where all human–computer interactions are examined without involving users (Mahatody et al., 2010). This method was chosen, considering that the GICMED app is still being developed and is not yet functional enough for user testing. Since the application is a medical digital product, more knowledge is required about the target groups and how they interact with digital technologies. The usability inspection was therefore conducted after the field research, in order to walkthrough the interface while keeping in mind the context and tasks the user needs to accomplish.

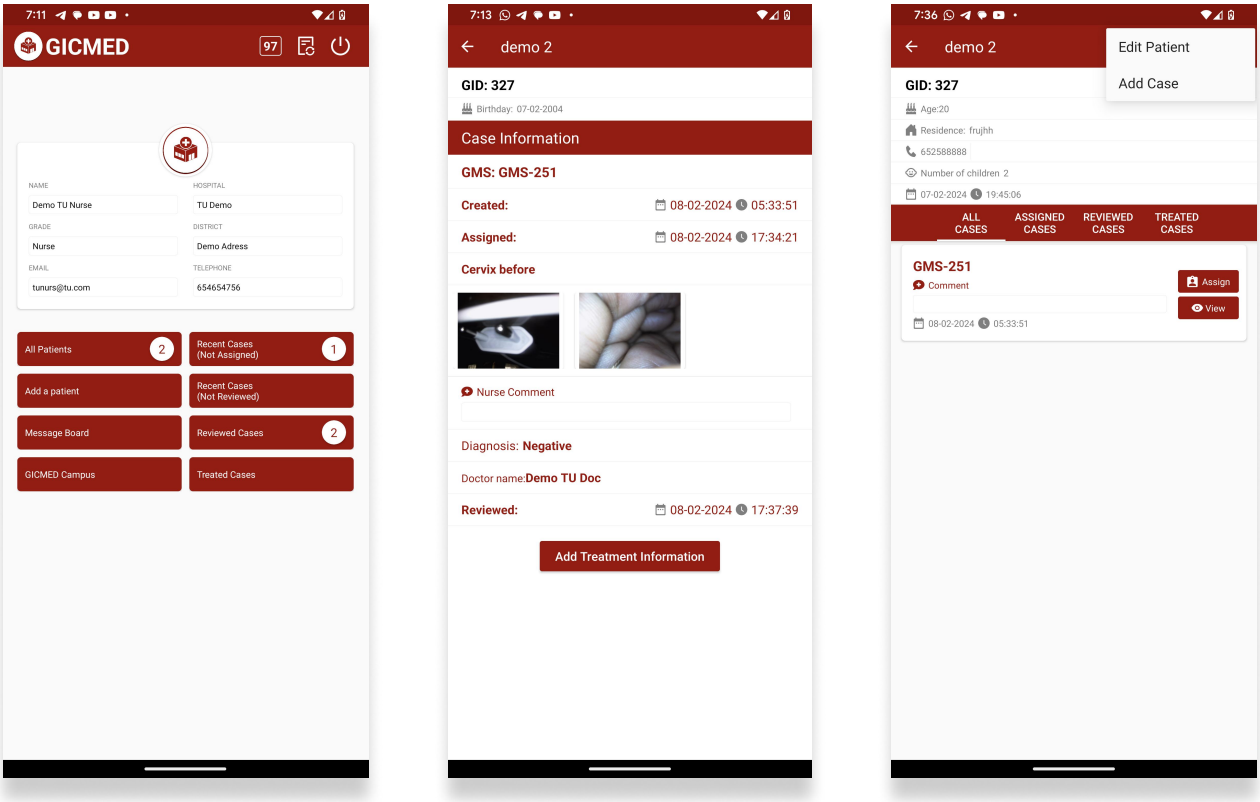


Figure 9: Three different views from the GICMED application

Procedure

Twelve formulated user goals served as tasks that were executed with the GICMED app. These tasks were completed in a manner that one would expect the user would perform them. While carefully completing each task, the app's actions and responses were compared to the knowledge of users and the user goals. Mismatches between what the user would anticipate and the actions demanded by the interface were observed.

User goals:

1. Getting access to the application
2. Viewing all registered patients
3. Adding a new patient
4. Filling in the details of the patient
5. Adding a new screening
6. Taking photos or videos while screening
7. Seeing the output of the camera
8. Filling in the results of the screening
9. Assigning a case to another doctor
10. Adding treatment information after screening
11. Viewing which cases have been assigned, reviewed or have received treatment
12. Editing patient details

Results

Four potential usability issues emerged while conducting the cognitive walkthrough:

- The current app provides **too many options** on one screen.
  - By presenting too many options to choose from, it is less likely that the user will know what to do.
  - This could lead to user disengagement.

- There are **some obscured controls** in the menu, which should be present while an action takes place.
  - If some controls are hidden, it is unlikely that the user will know what to do.

- The use of language is good. **Neither overly complex words** nor **industry jargon** are used.

- It takes some time to figure out where to find everything (**no clear hierarchy**).

- The app **rarely provides feedback** to let users know about their progress in the task (only once: when patient data is added successfully).

2.1.3 Agreements on Interaction with C-Spec

To ensure that everyone involved in the project would steer in the same direction, certain agreements had to be made. Specifically for the redesign of the GICMED app, it was crucial to determine what would be the optimal way of interacting with the C-Spec (Figure 10). Hence, the following consensus was made with the AED students:

1. The positioning of the smartphone

It should be possible for the user to position the smartphone on their arm in a way they feel most comfortable or that would be most ideal for them, whether that be on the outside of their lower forearm or on the inside.

2. Single-user focus

In a hospital, health center or during health campaigns, you do not want medical personnel to always be at one examination or procedure, as you want to be able to help as many patients as possible. The user should therefore be able to conduct the screening independently.

2. Preventing smartphone contamination

What stood out from observations at CBC, was the habit of touching the screen of the IRIS, a digital colposcope which is being piloted there, while screening (see chapter 3.2.2). This can result in contamination with potentially harmful bodily fluids for the patient, such as blood, pus and vaginal secretions (Sellors & Sankaranarayanan, 2003). That is why the decision was made that all interactions should occur on the device itself and not on the smartphone during the procedure. All the buttons and controls should therefore be located on the Smart Speculum and controlled manually. The app should only be used during the screening to check and judge the quality of the pictures.

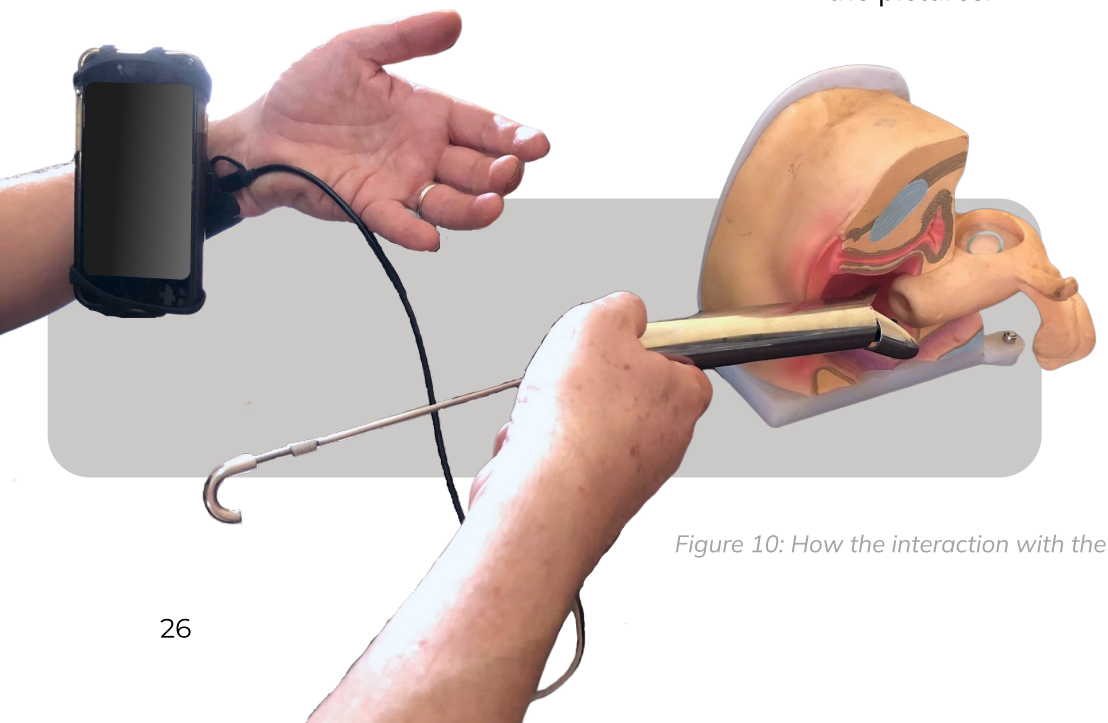


Figure 10: How the interaction with the C-Spec is currently designed

2.2
Field Research

In order to develop a comprehensive understanding of the context, stakeholders were interviewed and observations were done in health facilities in Cameroon. With the insights gathered, four User Journey Maps were created in order to identify design opportunities and formulate an assignment for this project.

2.2.1 User Journey Maps

While considering the diverse settings in which CCS are carried out and the various healthcare providers who can perform it, a focus had to be established. This way, User Journey Maps could be filled in specifically for that setting and user to investigate perceived experiences. The pains, gains and emotions during certain activities within the stages of CCS were explored, and this included taking a closer examination of the devices and forms of interaction used.

The selected setting for highly trained medical professionals

In LRS, a differentiation can be drawn between screenings conducted in hospitals and community-driven health campaigns. Four User Journey Maps were therefore made to bring two different perspectives (see selection of the aforementioned user groups in chapter 2.1.1), to both settings and explore design opportunities.

The main focus for highly trained medical professionals was set on CCS performed in Regional Hospitals & District Hospitals, and CCS conducted during health campaigns. The decision for these two hospitals is based on the fact that cervical cancer care at these facilities is primarily provided by highly trained medical professionals.

The selected healthcare facility for less trained healthcare providers

The main focus for less trained healthcare providers, was set on CCS performed in CBC Hospitals in Cameroon, and CCS conducted during health campaigns. This decision was made upon the discovery that many nurses and midwives, who fit within this user group, never perform screenings. Especially the ones working in Integrated Health Centers and District Hospitals (see chapter 2.1.1 for a description of the different healthcare levels and corresponding facilities) commonly refer patients when a screening is needed. In Integrated Health Centres, screenings are solely performed when a campaign is held, which is once or twice a year. In contrast, CBC has a specific department in their hospitals, the Women's Health Department, for conducting CCS and the nurses there are accustomed to performing them.

User Journey Map 1

Highly Trained Medical Professionals in Regional and District Hospitals

Women in Cameroon rarely ask for a CCS when they go the hospital. Most of the time, patients come in with certain complaints, and depending on their age and when they started to become sexually active, the medical professional recommends to conduct a screening. A major factor why people do not go for cervical cancer examinations, is because they cannot afford it. Women frequently think having cancer equals death, as they cannot pay for the treatment. In addition, Cameronians have little trust in healthcare providers when going to the hospital as they know the quality of equipment and staff is generally quite low.

GPs have to take an additional training of one day in order to conduct CCS. Although there are many languages in Cameroon, the professionals are able to communicate well with patients in English, Pidgin English or French. Based on the client's symptoms a recommendation is done whether a CCS would be necessary. After the client has paid at a separate counter, she comes back to the examination room where intake forms are filled in if the client is a new patient. In most cases, women from the age of 30 are recommended to be examined. However, clients who have had many sexual partners, have become sexually active from a young age or live with HIV (Human Immunodeficiency Virus), are also recommend to be screened.

Conducting the screening

GPs and gynaecologists mostly conduct both VIA and VILI tests, because using one of those methods exclusively would be insufficient. HPV-DNA tests are almost never conducted, since they are too expensive for patients (the costs are more than the double than for VIA or VILI). This type of screening requires expensive machinery and involves different hospital staff, which imposes additional costs. In addition, the value of the VIA and VILI methods is that they provide quite some flexibility, as images can be kept and transferred to other medical personnel. These tests are also a lot cheaper, which implies they can be done multiple times.

Making pictures of cervix

The professionals make use of the Smart Scope (see chapter 3.2.3) or smartphones (Android) to make photos of the cervix. The photos made can be compared to example pictures of cervices with cancer in their examination room to facilitate diagnosis.

Reaching a diagnosis

A general practitioner shared that he only refers 1 in 10 cases to a gynaecologist. There can be several gynaecologists in the hospital that can be called for referral, while the patient waits. If the patient does not have enough money for a new screening, the first screening will be for free and the client gets referred to a gynaecologist who does the procedure again, and perhaps performs a biopsy. If a biopsy is taken, which is rare (5% of the times), the patient gets referred to a lab technician in the same hospital who will analyse the sample. It will take about a month before this technician (who is a pathologist) has analysed the sample and sent the result back to the general practitioner.

Patients are frequently referred to gynaecologists who will decide if the case is 'negative', 'positive' or 'suspicious' for precancerous lesions. If the outcome is 'positive', the gynaecologist will decide on the type of treatment needed and if it is 'suspicious' a biopsy will be taken.

Processing the CCS

Some medical professionals explained that they get worn out by filling in all the different forms and books to process the screening. The app could reduce the amount of paperwork that has to be filled in by combining the forms and registration book and leaving out any repetition. In that way, the medical professionals can be more efficient as they have more time to take care of patients.

Loss of follow-up

There are quite some patients who get lost for follow-up, even though they:

- Have to receive and discuss their HPV-DNA result
- Are in need of treatment
- Have to undergo a new screening, because the outcome of the previous one was inconclusive.

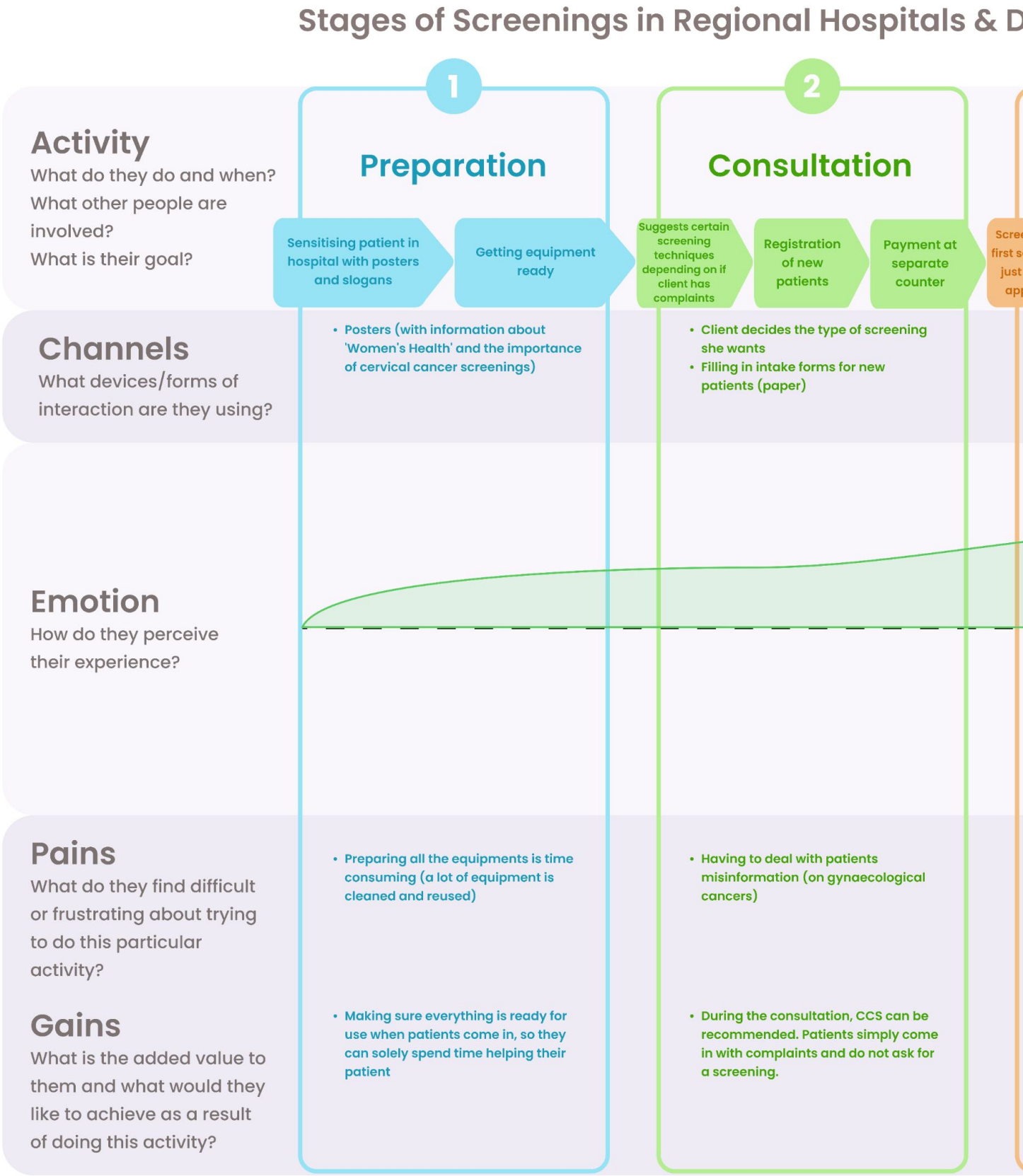
Given the possibility that lives could be saved if follow-up took place, this issue should be addressed.

Providing guidance

Generally, the highly trained medical professionals have more experience and knowledge to provide an accurate diagnosis. However, field research revealed that a few individuals had conducted CCS in the past, but have not engaged in it for a long period of time or had practised it during their study, but rarely in the field. Hence, the conclusion was made that both this user group and the less trained healthcare providers would benefit from guidance throughout the screening process.

User Journey Map 1.

Highly Trained Medical Professionals



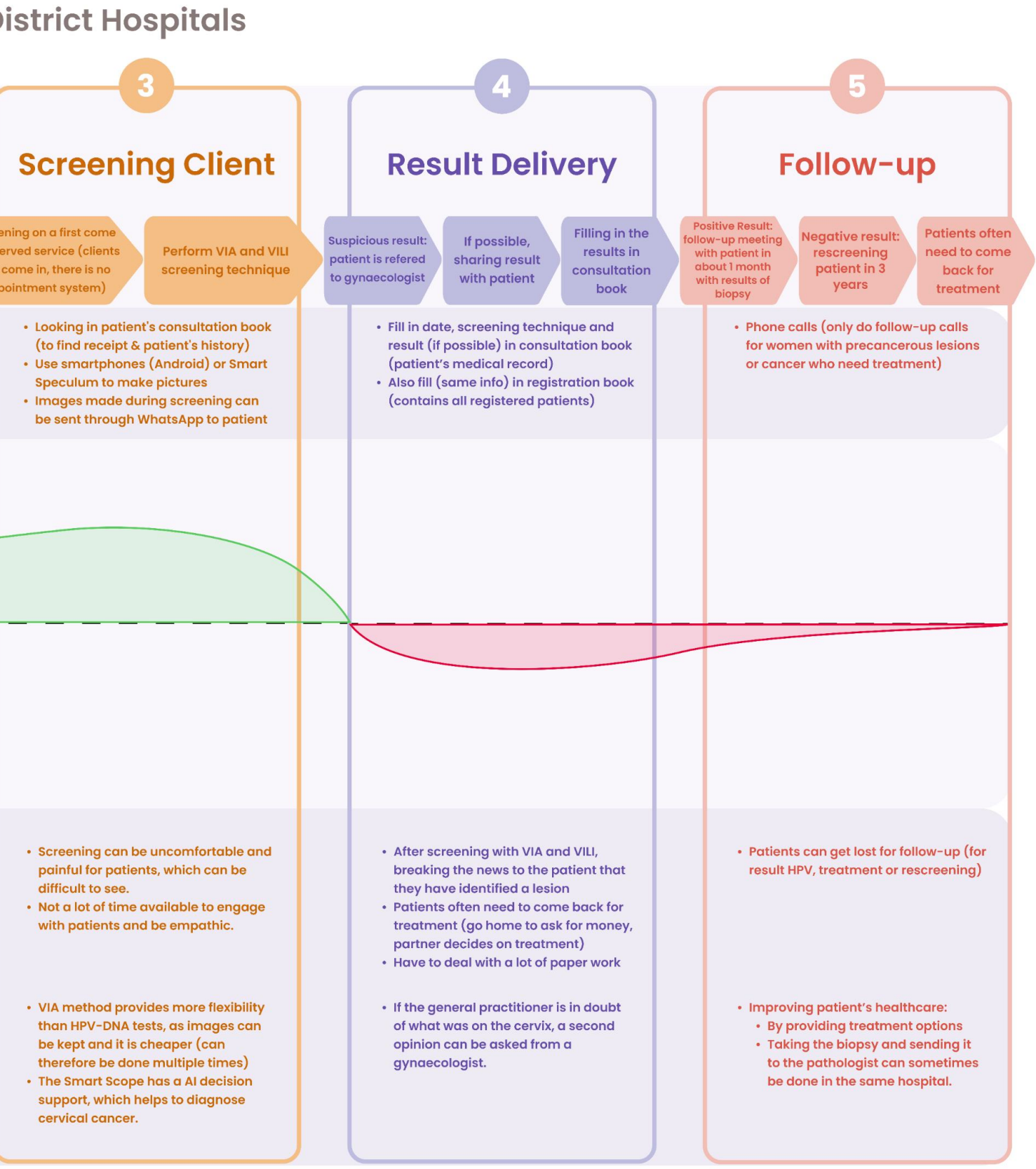


Figure 11: User Journey Map displaying the experience of highly trained medical professionals in hospitals

User Journey Map 2

Highly Trained Medical Professionals in Health Campaigns

Four Resident Doctors were invited to the GIC Space office (see Figure 12), to gain a deeper understanding of how they conduct CCS during health campaigns. Resident doctors are gynaecologists (specialists in training) who perform all types of CCS: VIA/VILI, HPV-DNA and PAP smear, and they carry out major surgery on cancer cases. These doctors therefore also belong to the highly trained medical professionals group. Since these specialists work in more advanced hospitals (Central Hospitals) and not in Regional and/or District hospitals, they were excluded from User Journey Map 1. Resident Doctors regularly participate in health campaigns and their experiences are therefore of interest.

With health campaigns, women in rural settings can be reached to raise awareness about the important of CCS and to conduct screenings. Although this number can vary, the resident doctors revealed that approximately 500 women were examined in a previous campaign. Different healthcare providers are involved, such as gynaecologists (who lead the nurses), nurses, medical students and community workers. Women in rural areas hear about the campaign through posters, media (tv or radio) or from their traditional (phone or chief) or religious leaders (pastors & preachers). These leaders are approached to convince people to get screened, since women tend to trust them more than healthcare providers, and the leader's permission is needed to host a campaign at their village. Since CCS at health campaigns are often paid by the government and, thus, are free of charge, it is possible to get in touch with women who are normally not able to come to a healthcare facility (due to their remoteness and expenses).

In each room where CCS are performed, there is one person for registering patients and another to conduct the screening. A supervisor (highly trained medical professional) walks around to assist with challenging cases. When the supervisor is unsure about the outcome, the patient has to return to a hospital for a new screening.

Community health workers

Community workers are mediators who are part of the community where the campaign is held. These people share information with local residents about the campaign, receive patients during campaigns and are the bridge between the administration in the hospital and in the community. The community workers understand best what type of health campaign would be needed and can tell if a CCS campaign would be successful in a certain community.

Positive interaction with patients

According to the resident doctors, health campaigns are generally perceived as a positive experience, as they provide the unique opportunity to interact with each patient and build a personal relationship with them. At campaigns, there is often more time available to engage with patients and as a result, women learn to trust healthcare providers.

Processing the CCS

Depending on what is at hand, there can be made use of smartphones or digital

colposcopes to make pictures of the cervix.

The findings of the CCS can be entered on an A5 paper:

- Where can be indicated whether the VIA and/or VILI test was positive or negative.
- A description of the lesion and where it was found, e.g. at 8 o'clock, can be provided.
- And a recommendation can be given on how to move forward.
- If a breast exam was carried out simultaneously, those findings can be written on this paper as well.

The A5 papers are put in the consultation booklet of the client (notebook containing the patient's medical history), and a type of registration book specifically for screenings (containing all registered patients), is updated.

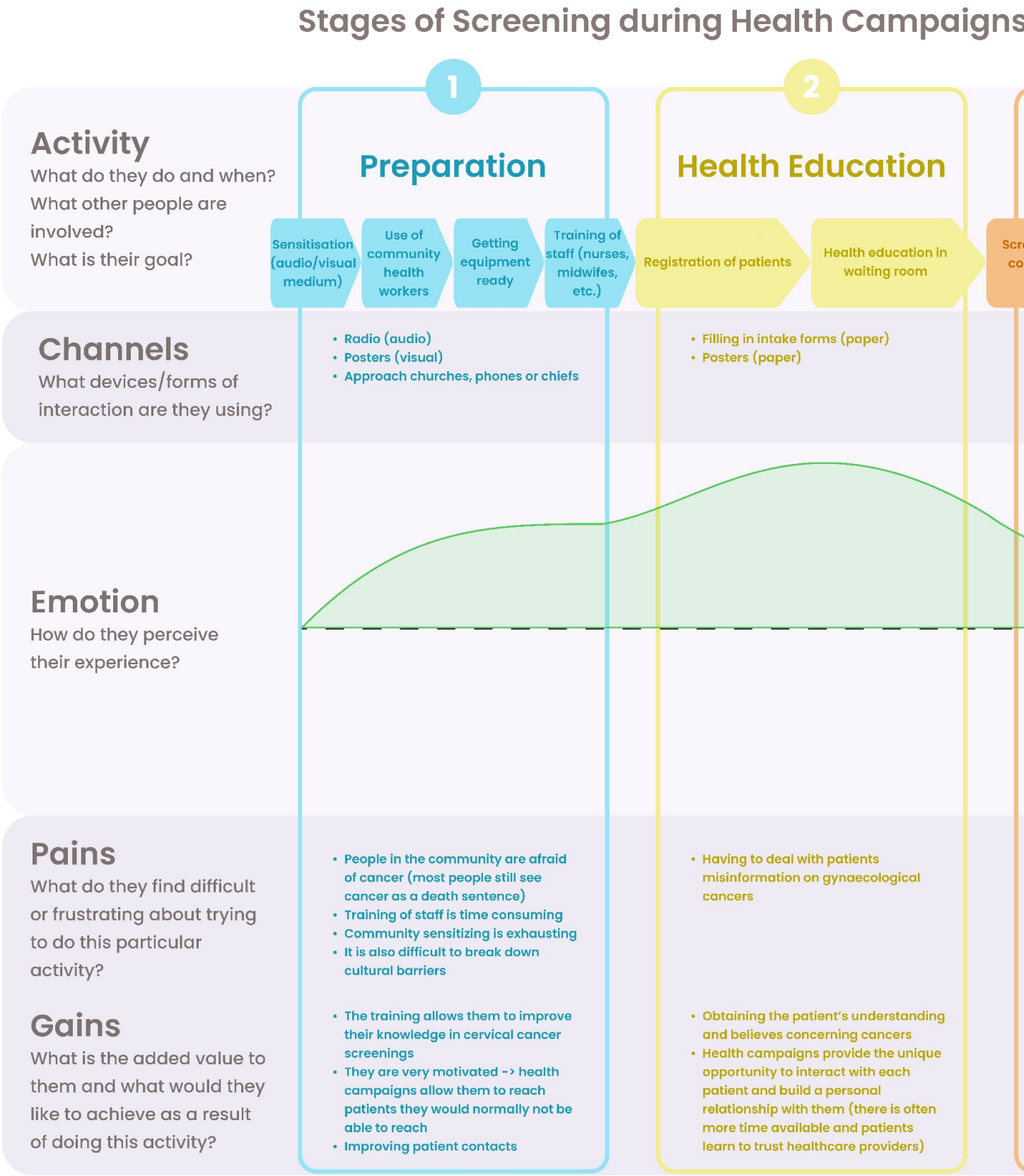
Loss of follow-up

After a campaign is held, it is rare for highly trained medical professionals to assist in keeping track of patients. Often, community workers are the ones responsible for conducting follow-up and either call clients or go to the patient's residence to get them to a hospital. Patients often have scepticism against hospitals and, as a result, do not always come back for follow-up visits. They must therefore be slightly pushed in order to seek the care that they require.

Figure 12: The creation of User Journey Map 2

User Journey Map 2.

Highly Trained Medical Professionals



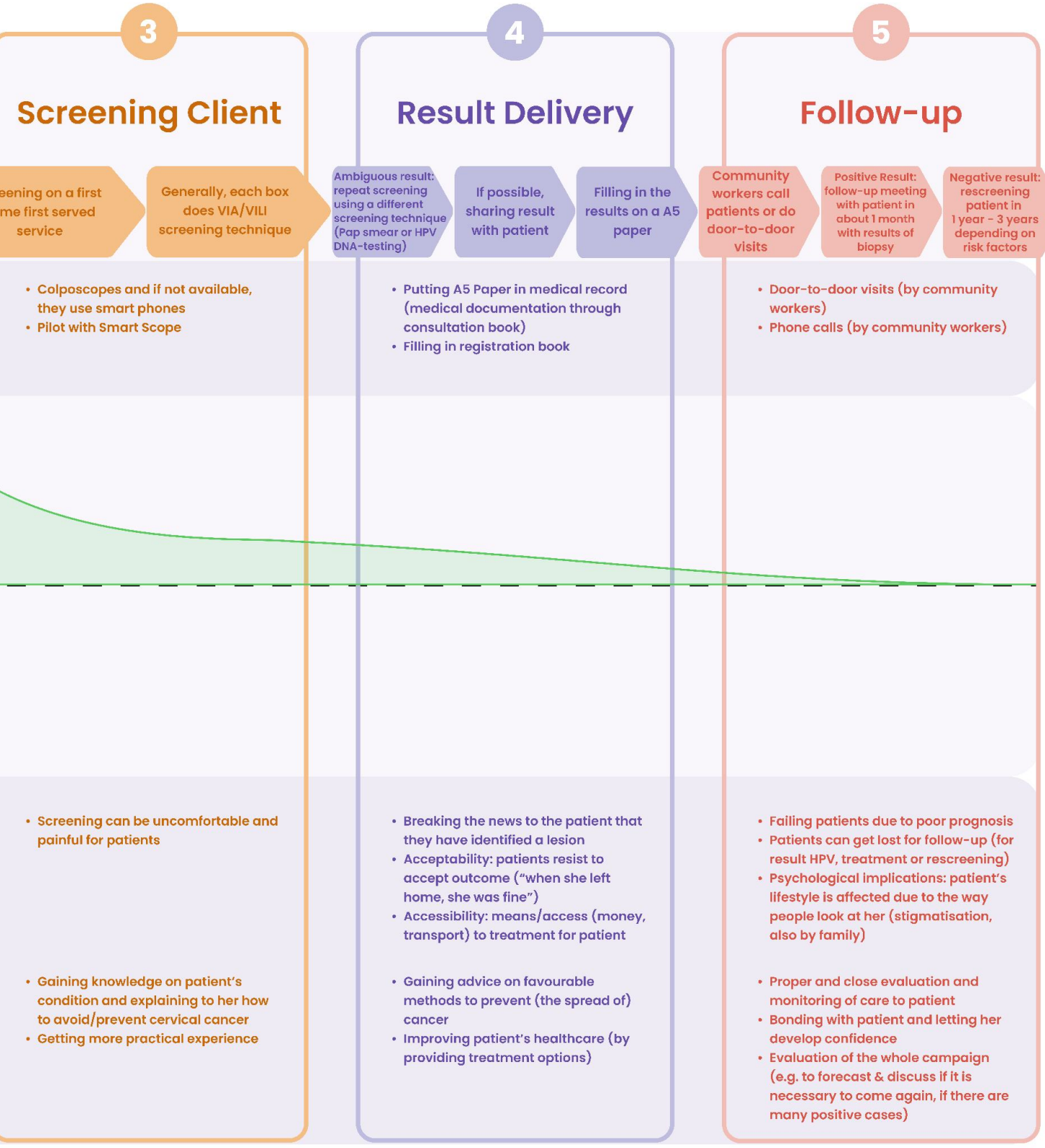


Figure 13: User Journey Map displaying the experience of highly trained medical professionals during health campaigns

User Journey Map 3

Less Trained Healthcare Providers in CBC Hospitals

The nurse who runs the Women's Health Department at CBC, explained that the Women's Health Program handles not only CCS and prevention, but also breast cancer screening, family planning services and treatment of reproductive tract infections (RTI's). This User Journey, like all others, specifically zoomed in on the experiences perceived throughout the CCS process. The Women's Health Program is led by nurses.

Screenings at CBC are carried out in a organised manner, similar to how screenings are conducted by highly trained medical professionals (User Journey Map 1). There is no appointment system, so patients simply come in when needed. Although women often have certain complaints, they rarely ask for a CCS during the consultation. The nurse therefore explains which type of screening she recommends based on the client's symptoms. After the client has paid at a separate counter, she comes back to the examination room where intake forms are filled in if the client is a new patient, and after that the screening can be performed.

Digital Transformation

The nurses at the Women's Health Department have started integrating digital technology into the procedure and are getting familiar with interacting with these products. First, they began using digital cameras to capture images for quality assurance, so they could check if the result was actually true. Years later they switched to smartphones (Samsung Galaxy X4) to improve the image quality. Recently, digital colposcopes were introduced (first EVAPro then IRIS, see chapters 3.2.1 & 3.2.2) to zoom in even more while maintaining a high quality picture. Even though they have switched from smartphones to digital colposcopes, nowadays one of the latest smartphones could reasonably ensure the same photo quality.

The IRIS was a gift from gynaecologists from the USA and is still being piloted at CBC. What was striking is that the product gave few instructions while entering the findings of the screening, and the nurses were not familiar with the meaning of some terminology. As described in the Problem Definition in 1.2.1, the repercussions of this incorrect usage can lead to adverse health outcomes and potential cost implications (World Health Organization, 2012). It is therefore crucial for the redesign of the application, that nurses are guided through the flow and given clarifications where necessary.

Reaching a diagnosis

When the nurses are not sure about what they saw while screening, they request assistance from the head nurse who will check the images made. If this individual is also unsure, the pictures are forwarded to a WhatsApp group containing experts and specialists from abroad (USA, Canada, Mexico), such as gynaecologists, oncologists and dermatologists, and other nurses from Cameroon. The intention of this group chat is to discuss pictures and devise a treatment plan in order to reduce patient waiting time and let treatment commence as soon as possible. After multiple responses have arrived, the nurses review them and go for the answer that is more convenient and beneficial.

In case no definite conclusion could be drawn from the photos in the WhatsApp group, there is a 'Eco call' once a month via Zoom. All specialists and doctors in the WhatsApp group are invited to discuss a case even more and recommend what to do next. Two nurses described that they enjoy these meetings, since they provide the opportunity to expand their knowledge. The current GICMED addresses this need by providing remote diagnosis, in which users can assign cases to other doctors.

Processing the CCS

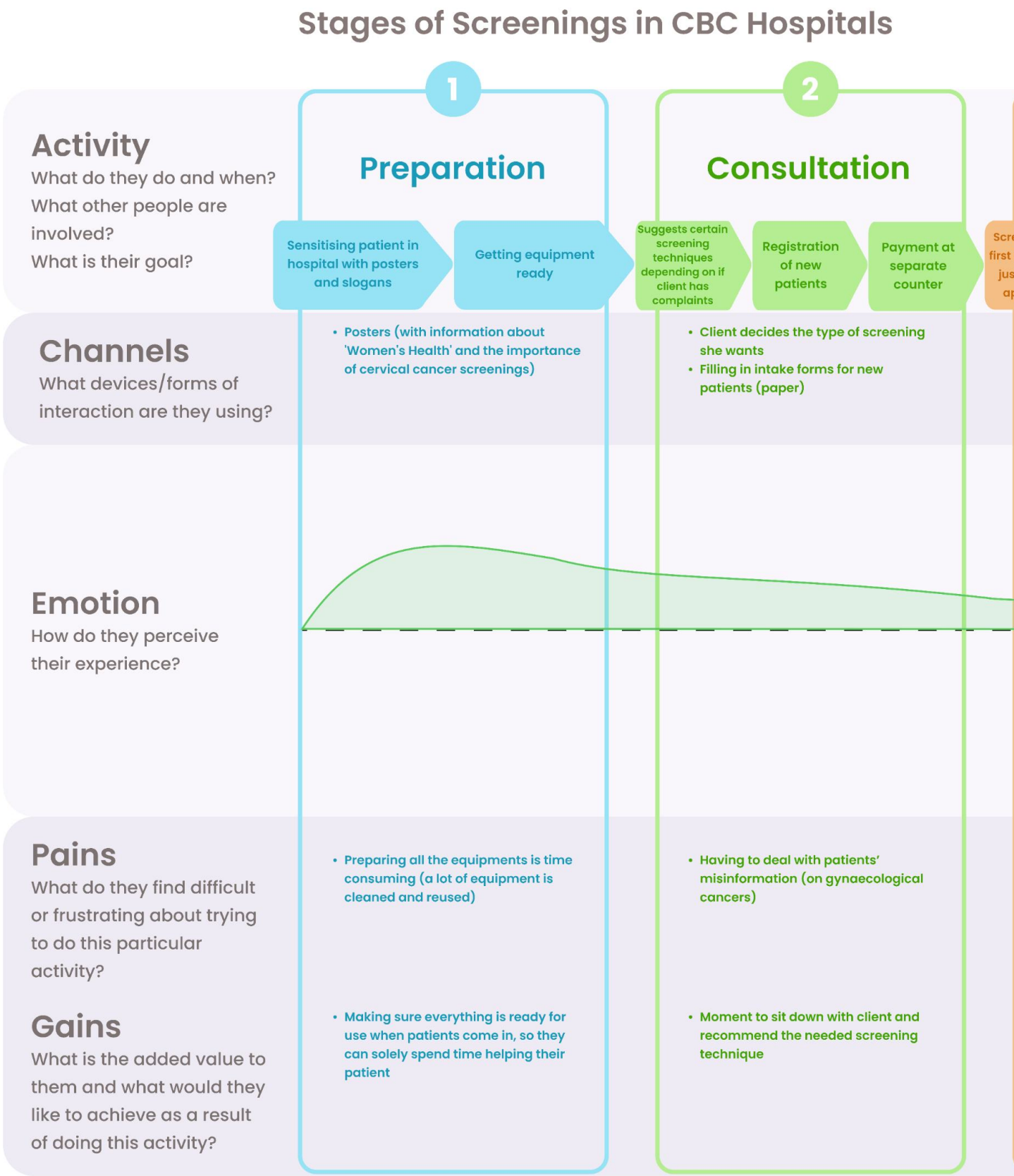
To process the outcome of the screening, several papers have to be filled in by hand: the consultation book of the patient, which contains their medical history, and the registration book containing all registered patients. In addition, before the screening was carried out, the intake forms had to be completed as well. All these combined take up a considerable amount of work and might explain why depression is very common among nurses in Cameroon (see chapter 2.1.1).

Loss of follow-up

What was striking about this User Journey is that quite some patients get lost for follow-up. The nurses at CBC emphasise to patients that they need to return to the hospital for the follow-up visit, however, only women in need of treatment are called.

User Journey Map 3.

Less Trained Healthcare Providers



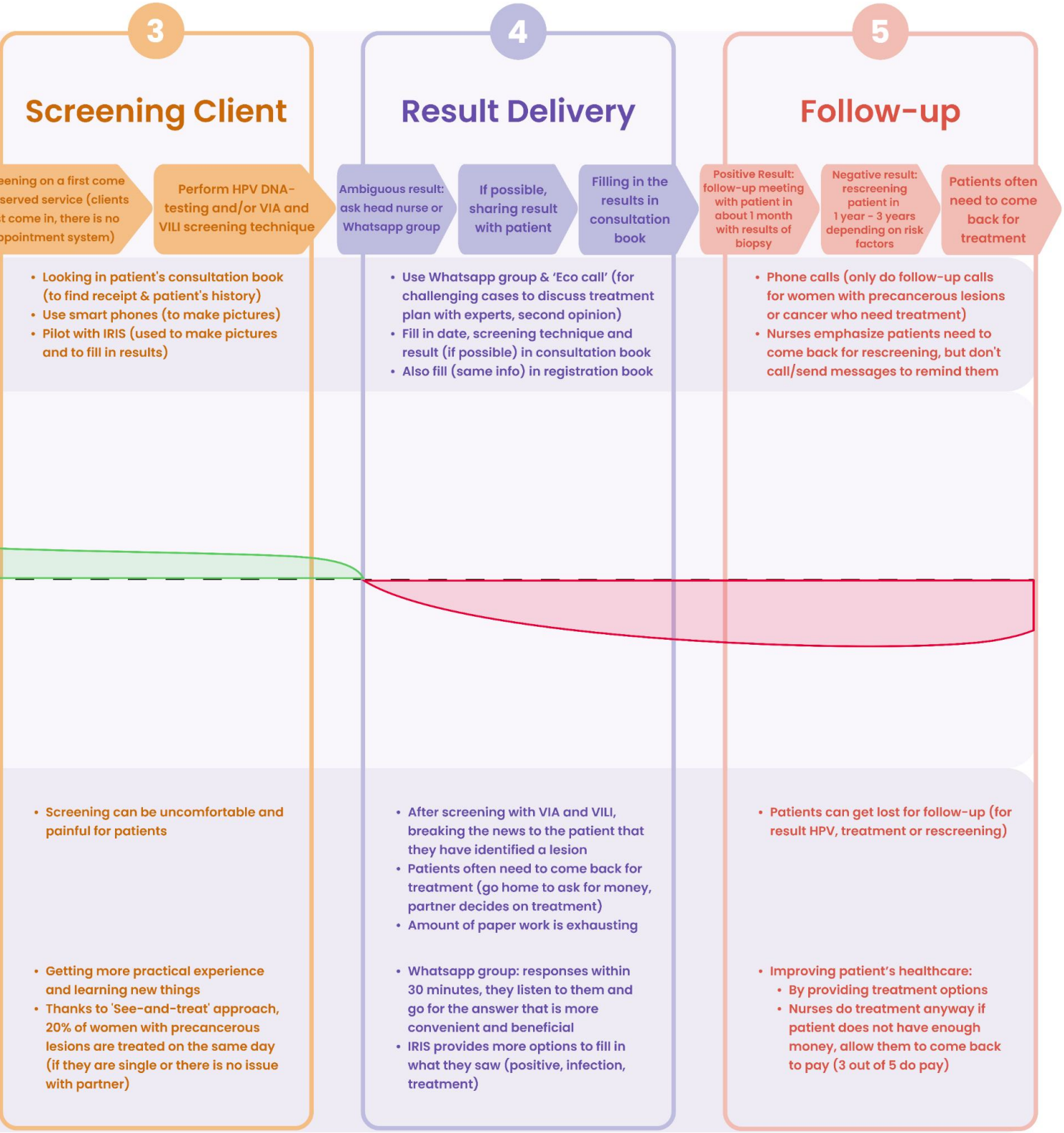


Figure 14: User Journey Map displaying the experience of less trained healthcare providers in CBC hospitals

User Journey Map 4

Less Trained Healthcare Providers in Health Campaigns

Since women do not come to hospitals on their own accord to undergo a CCS, it is crucial that examinations take place closer to home in health centers or in a mobile setting. Campaigns can be held once or twice a year and, can take around three days, and depending on the location of the event, about 50 to 200 women can get checked. A campaign can have 4 GPs, 2 midwives, 10 nurses and no gynaecologists. The nurses and midwives conduct the CCS and sometimes train medical students, whereas GPs serve as supervisors. Before the campaign kicks off, camps are set up if no health facility is available, and pre-enrolment of patients begins. Each woman is given a number and called to remind them to come in and get screened. Although CCS are often free at health campaigns, clients do need to pay for treatment.

Similar to User Journey Map 2, traditional or religious leaders from the villages are used to convince people to get screened. The main difference between the two maps is that less trained healthcare providers do not conduct health education in waiting rooms, but in stead clarify what screening for cervical cancer is about in de examination rooms.

Conducting the screening

Some healthcare providers said they perform both VIA and VILI tests, while others only conduct VILI tests during campaigns. When there are doubts about what exactly can be seen on the cervix, an expert (often a general practitioner) can be asked to take a look. If the GP is unable to determine whether it is a precancerous lesion, the patient will either be referred or a biopsy will be taken.

Making pictures of cervix

Depending on the health facility the healthcare providers comes from, there can either be made use of smartphones or digital colposcopes to make pictures. There are also healthcare workers who do not take photos and just ask a specialist on site for a second opinion.

Processing the CCS

Similar to how highly trained medical professionals deliver the result, (see User Journey Map 2), the outcome of CCS during health campaigns are filled in on a A5 paper. The difference between the two Maps is that the less trained healthcare providers keep the papers for data analysis and do not give them to patients.

Similarly to what has been discovered in User Journey Map 1, 3 and 4, less trained healthcare providers spent a lot of time on paperwork, which the redesign of the app could reduce.

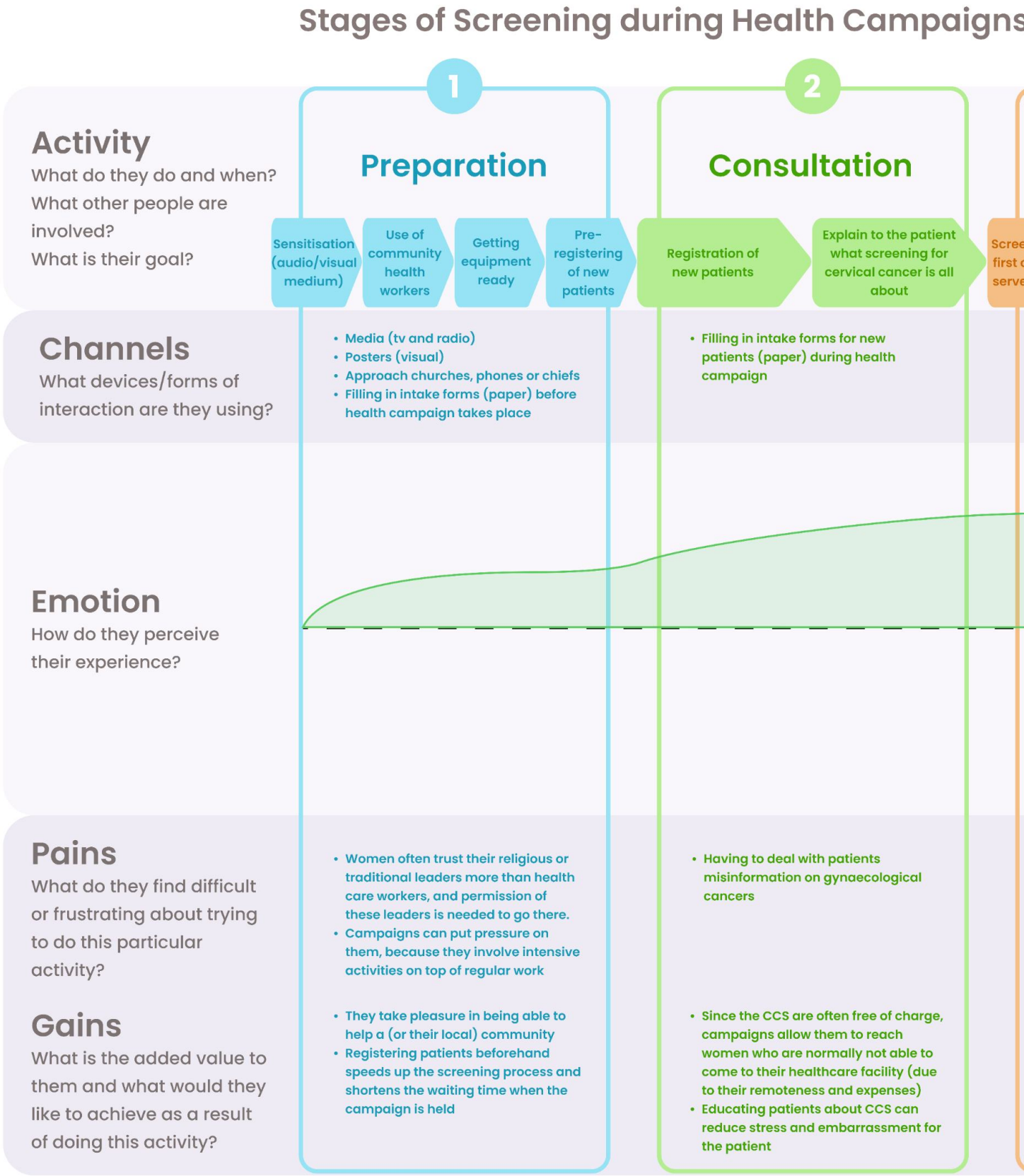
Loss of follow-up

Another recurring concern is the loss of follow-up. In case of health campaigns, follow-up can either be done by community workers or healthcare providers who assisted during the campaign, and is in that way often easier to manage. Community workers know the community where the campaign is held very well, and will call patients or even do door-to-door visits to identify which issue is keeping them from going to the hospital for follow-up. Healthcare providers assist in tracking patients and occasionally follow up in a consult after a campaign.

Figure 15: The way interviews were conducted in the field

User Journey Map 4.

Less Trained Healthcare Providers



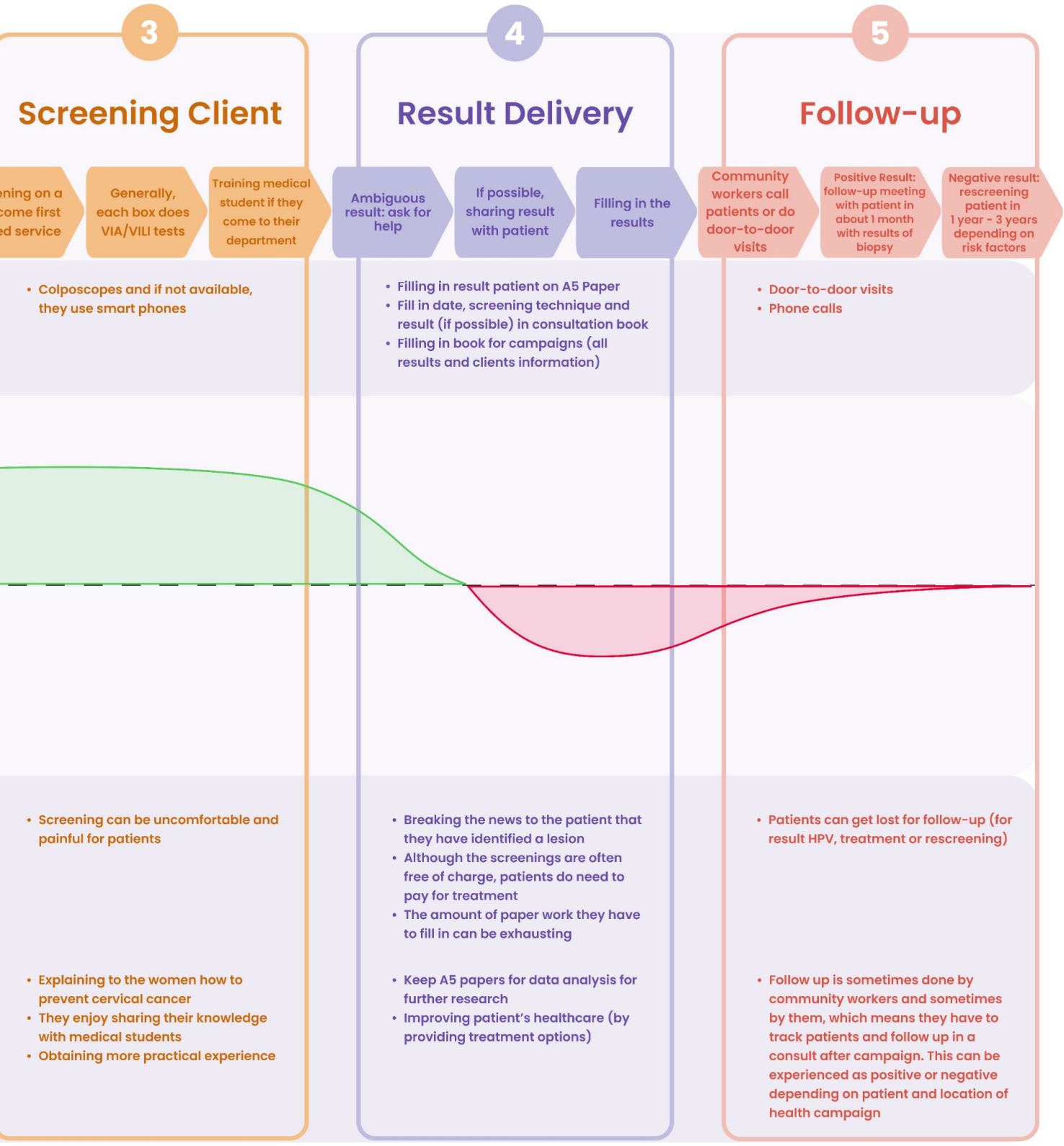


Figure 16: User Journey Map displaying the experience of less trained healthcare providers during health campaigns

2.2.2 Design Opportunities

The findings and conclusions made of the User Journey Maps have been translated into design opportunities. Out of the four potential directions, design direction 1 and 2 were selected to design for. These two closely align with user needs and are feasible within the available amount of time.

Design Direction 1

From User Journey Maps 1, 3 and 4, it has become evident that healthcare providers in LRS who perform CCS spent a lot of time on paperwork, leaving little time to engage with patients and express empathy. Hence, the redesign of the current GICMED application should make paperwork less of an obstacle and enhance the interaction between patient and healthcare provider.

Design Direction 2

There is a lot of loss of follow-up of patients screened. The redesign should therefore assist healthcare providers to keep track of patient data more efficiently, allowing them to notify patients who need to be reminded about follow-up or need to be stimulated to undergo treatment.

Design Direction 3

Although healthcare workers are trained to perform CCS, they often lack experience and expertise to accurately diagnose precancerous lesions. The app could therefore serve as a training support for personnel.

Design Direction 4

Several digital products and software programs are being used across different health facilities. This means there is a lot of data and information that cannot be exchanged between these facilities. The application could therefore connect these devices and systems, or reorganise how work is done.

Since GIC Space ultimately wants to achieve that both the Smart Speculum and corresponding app can be used in hospitals and health centers (chapter 2.2.3), the redesign of the GICMED app is based on the way CBC hospitals are generally organised (see User Journey Map 3). Still, the design's applicability to health campaigns was taken into consideration at every step throughout the design process. GIC Space already has an ethical clearance in place at a CBC hospital and this hospital also has the means to eventually purchase the device, which is why this would be a good place to start implementing the design.

2.2.3 Assignment

The objectives for this project are split into an end goal and a design goal. The end goal indicates the desired outcome that GIC Space ultimately wants to accomplish with their physical and digital product. The design goal states what this MSc thesis aims to achieve and what will be delivered at the end of the project (Figure 17).

End goal

During a discussion with Dr. Conrad and Karl, it became clear that it would be ideal if there would be no need for health campaigns. If regular healthcare services were comprehensive and reached all women in the country effectively, there would be no need for supplementary campaigns. However, for now, they are still needed and therefore the single-user focus remains crucial. The idea is that in the long run, screenings will happen in health centers and it would also be convenient there if the app could be used by a single person.

Design goal

Enhancing the patient-caregiver interaction, entails allowing personnel to work in a efficient manner and devote more time to providing care to patients. By assisting medical workers in keeping track of patient data, women who need to be reminded about follow-up or need to be stimulated to undergo treatment, can be notified.

In their efforts to commercialize innovative technologies, companies frequently encounter resource constraints. It is therefore recommended to implement the model of a lean startup, as its concept promotes efficient use of resources by rapidly launching a MVP to determine whether an innovative concept is viable. The MVP should be a first model of the product that is sufficiently complete to prove its value. While an MVP should take less time to development and should concentrate on a fundamental set of features, it should also incorporate capabilities to measure its market traction (Moogk, 2012).

End Goal:
Making sure that the Smart Speculum and corresponding app can be used in hospitals and health centers, so there is **no need for health campaigns!**

Design Goal
Redesign the current GICMED smartphone application and create a digital prototype (Minimum Viable Product) to **enhance the interaction between patient and healthcare provider** in Low Resource Settings who perform CCS, and **help** these healthcare providers **to keep track of patient data more efficiently**.

Figure 17: End goal & design goal

3. IDEATION

After the objectives and assignment for this project were defined, it was time to start ideating. By reviewing several medical app designs, an inspiration board was formed to determine the look and feel that the GICMED app should have. A benchmark provided insight into which well-conceived design features have been implemented by competitors and should be implemented in the redesign. And finally, generated ideas were translated into a first set of wireframes to form an initial design proposal.

3.1
The Redesign's Look and Feel

Besides that the features, functionalities and the user experience of a digital product must be well considered, a great look and feel is also extremely important. That is why several designs of medical apps were reviewed and put together, to determine the look and feel for the redesign of the GICMED app (Figure 18).

Designing user interfaces involves including necessary elements for the "look", such as fonts, colour and layouts, but also interactive components like buttons, menus and textboxes for the "feel". While there are numerous design principles, those that have the greatest affect on the design of smartphone applications are hierarchy, consistency and personality (Schlatter & Levinson, 2013).

Hierarchy

The perception and interpretation of the significance of elements on the display is known as visual hierarchy. A digital product can only be regarded as functional if it is capable of demonstrating its functionalities and effectively communicating how they should be used. To assist users in comprehending what to look at first, Schlatter and Levinson (2013) recommend making well-considered choices about placement, size, typography, contrast, use of colour and layout.

Consistency

Creating consistency is about setting and upholding expectations, by employing components that people are accustomed to (Schlatter & Levinson, 2013). Given that people's expectations are shaped by both what they see on screen and what they have seen before, there was explored what digital products medical professionals are already using in Cameroon to see what can be adopted from those products (see chapter 3.2 Benchmark with Competitors).

Personality

The personality of a digital product, the visual components that shape users' perceptions of it, help to form expectations about its functionality and target audience. The defined characteristics of the app's personality should be applicable to the entire project (Schlatter & Levinson, 2013). The style and colours currently used for the GICMED environment will therefore serve as a foundation for the redesign.

Based on the inspiration board in Figure **X**, the user interface should have a calm and modest look and feel with a neutral basis, and occasional pops of colour to highlight certain features and maintain an aesthetically pleasant design. In addition, the examination of the inspiration board together with discussions with nurses at CBC, revealed that the design should be straightforward without having to navigate much through the app. The application should therefore only be equipped with tools and functionalities that will assist both user groups in achieving their goals. If more or less features are added, users will probably deem the app irrelevant or unusable. In order to make the user interface as clear as possible, it was decided that only a few options should be presented to the user on each screen.

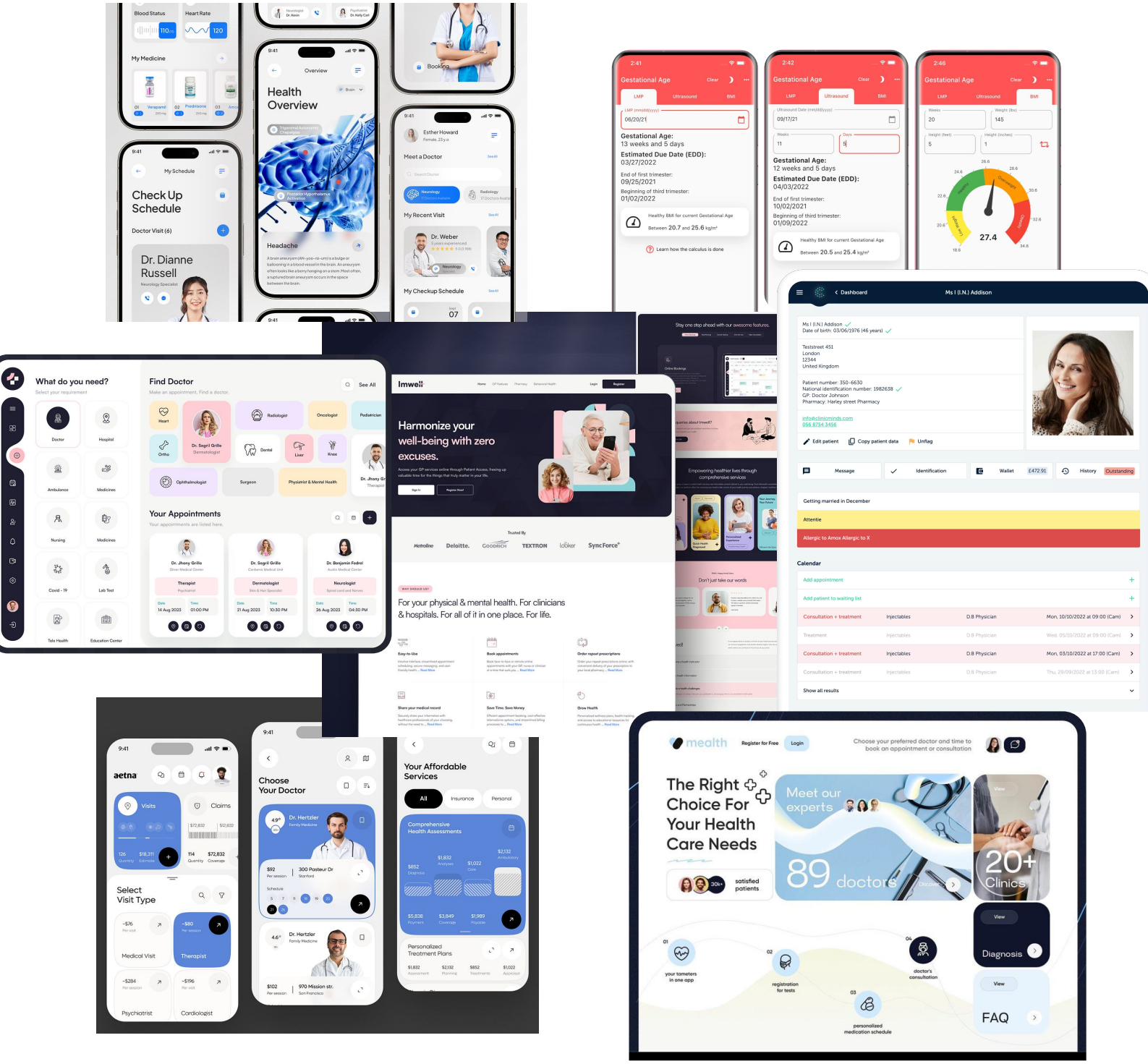


Figure 18: The created inspiration board displaying various medical app designs

3.2
Benchmark with Competitors

Four devices and technological innovations that are gradually making their appearance or are currently used for VIA and VILI tests in LRS, were analysed in this chapter. These inspected products serve as benchmarks to understand whether the features or functionalities these competitors offer, should be implemented in the redesign.

3.2.1 EVAPro

Great picture quality and visualization

The EVAPro (Figure 19) is a compact and portable digital colposcope launched by the company Mobile ODT. The device combines a built-in smartphone with an integrated optical lens to enable the user to take high quality magnified photos. One of the CBC hospitals visited during the field study, had not purchased the EVAPro but the EVASane, which is actually meant for sexual assault forensics and yet quite similar in its operation (Figure 20). This product was procured by them partly because the work phones they were using had no autofocus and the image quality was poor. There was also a desire for something that would allow them to zoom in more than 3 times.

Figure 19: The EVAPro (MobileODT, 2024)

Digital green filter

The device provides the option of adding a digital green filter to the screen. The benefit of the green filter is an enhanced visualisation of blood vessels, which may facilitate the identification of precancerous lesions (MobileODT, 2024). The nurses at CBC are enthusiastic about this feature and it was one of the main reasons why they switched from using smartphones to a digital colposcope.

EVA application

The EVAPro is accompanied by an application that offers the ability to document cases, and attach filters and explanatory notes (e.g. for biopsy) directly to pictures (MobileODT, 2024).

Electronic Medical Record

The offering includes a portal with a secure Electronic Medical Record (EMR) for online data management. Ehrenstein et al. (2019) clarifies that an EMR is a digital system employed in clinical care settings to record and store various types of medical data for each patient (Ehrenstein et al., 2019). Similarly, the EVA portal offers the opportunity to save, manage and export patient data with unlimited storage (MobileODT, 2024).

The medical professionals at CBC eventually stopped using the EVASane, because it was slow in uploading and downloading images, and it was costly to store photos in the cloud.

Educating women about their bodies

Another interesting advantage of the EVAPro is that the device makes it easy to communicate findings to patients on site. The digital cervicographs made can be presented to the patient to increase awareness and knowledge of the internal structure of their body (MobileODT, 2024). This way, women can learn about the importance of CCS and it can increase their confidence in the medical staff.

Figure 20: The EVASane (MobileODT, 2024)

3.2.2 IRIS

Another digital colposcope used for cervical cancer diagnosis, is the IRIS from Liger Medical. This product is quite similar to the EVAPro, yet differentiates itself by combining a digital colposcope with a thermocoagulator to offer both diagnosis and treatment in a single visit, see Figure 21 (Liger Medical, n.d.).

Great picture quality and visualization

The camera on the device has a high image resolution (2880x2016px) and autofocus to capture sharp pictures. The product comes with a flashlight and can magnify the cervix 4-10x for better visualization of the transformation zone (Liger Medical, n.d.). The nurses at CBC were particularly fond of the autofocus and magnification functionality, because it takes away the pressure of having to make sharp pictures.

Green filter application

Similar to the EVAPro, this device allows the user to apply a digital green filter while taking pictures. As mentioned in chapter 3.2.1, the green filter enhances the visualisation of blood vessels and the nurses at CBC added that it highlights unusual growths or deformities in blood vessels in the tissue.

Additional features that can be used while conducting the screening

There are two more features that the IRIS provides in which it differentiates from the EVAPro:

- The IRIS offers a countdown for the VIA test. After applying the acetic acid solution to the cervix, the user can click on a timer to initiate the 1-minute countdown, whereupon the results have to be reported. Since the button for the timer is located on the screen of the IRIS, there is a risk of contamination. For the redesign of the GICMED app, consideration was given to the possibility of adding screen protectors to smartphones, however these may harbour pathogenic bacteria and are hard to clean (Raza et al., 2017).
- The IRIS permits users to cast the screen of the device to a monitor. This allows the patient to observe her cervix during the procedure and provides healthcare providers the opportunity to elaborate on what they are seeing. Since this functionality requires a monitor in the examination room, it is not widely applicable to LRS.

Entering findings

The IRIS provides many options to fill in what was observed on the cervix, such as other diseases, infections or anomalies, and options with certain terminology that are required to reach a diagnosis. At the end of this ‘General Assessment’, a ‘Management Plan’ has to be established with whether biopsy, treatment or follow-up is needed. All provided options were evaluated with 4 resident doctors in Cameroon and were subsequently applied to the redesign of the GICMED application.

Electronic Medical Record

As with the EVAPro, this device incorporates a EMR to collect and manage patient data, and exchange health information. Having the ability to store data online significantly reduces the number of papers that need to be filled in and thereby saves time.

Exporting examinations

Uploading images or sessions to a computer can be done via a USB cable. For this and other ways of exporting, the decision can be made to export one session or all registered patients, and the option can be selected to send original images or an Excel file, which is specifically useful to send to the MOH. Exporting can be done via email, Wi-Fi, or a USB cable.

Since a internet connection is required for sending sessions via WI-FI or email, an addition option for the redesign could be Bluetooth. According to the nurses at CBC, there are Cameronians who are familiar with Bluetooth and frequently use it for playing music in their cars, so this could be a interesting addition.

Figure 21: The IRIS and ancillary equipment (Liger Medical, n.d.)

3.2.3 Smart Scope

The third and last digital colposcope discussed in this chapter, is the Smart Scope (see Figure 24) from Periwinkle Technologies. This product has gained competitive advantage by offering AI-enabled risk assessment and a ready-to-use set with acetic acid, Lugol's Iodine solution and cotton swabs (see Figure 23).

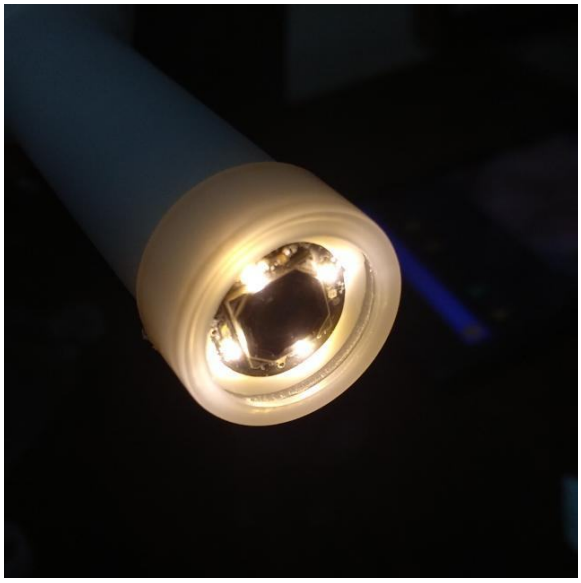


Figure 22: Build-in LEDs (Periwinkle Technologies, 2023)

Trans-vaginal screenings

The Smart Scope is designed for trans-vaginal screenings of cervical abnormalities and is based on WHO approved VIA and VILI screenings. This product has integrated white LEDs for uniform illumination (see Figure 22), and has a camera that can magnify up to 10 times. Due to its pencil-like shape and small size (22cm in length), the camera can be easily manoeuvred (Periwinkle Technologies, 2023).

As with the EVAPro and IRIS, a speculum has to be inserted before the devices can be put to use. The C-Spec from GIC Space will replace the speculum and will therefore be able to offer a more comfortable experience for the patient.

Figure 23: Disposable kit (Periwinkle Technologies, 2023)

Unique registration numbers

An EMR is offered to register each new patient with a unique digital number and to facilitate data management (Periwinkle Technologies, 2023).

Capturing images

According to a resident doctor who is testing this device, at least three pictures have to be made in order for the AI to make a diagnosis, and this can be done offline. The taken photos are stored locally with certain labels for future references. It does require an internet connection to analyse the images and upload them to the server.

AI-enabled software

The Smart Scope makes use of a software system with AI to generate a risk report within minutes. This auto-evaluation provides an accurate risk level assessment from the obtained images and can be printed in case the patient needs to be referred (Periwinkle Technologies, 2023).

Figure 24: The Smart Scope (Periwinkle Technologies, 2023)

3.2.4 DAMA

Electronic Health Record

A prototype of the Data Manager (DAMA) software system was recently introduced in a CBC hospital in Cameroon. The system essentially functions as an Electronic health record (EHR), which enables medical professionals to easily manage, store and monitor medical records while facilitating coordinated care across numerous facilities. EHRs are designed to share patient's medical information with every clinician involved, including laboratories and experts, and revolve around the overall health of the patient (Ehrenstein et al., 2019).

An alternative approach for organising hospitals

DAMA is being developed by software engineers working for CBC to improve the documentation of labour performed in healthcare facilities, and it demands a completely different approach to the way hospitals are structured. Before a new patient can come to the Women's Health Department, she must register at the hospital registration desk to get a unique patient number, which will be used at all CBC sites. A general consultation will take place and a new account is made available, unless the patient is already in the system. The software will make known when this occurs. The patient's personal information is obtained (Figure 25) and an order is send to the Women's Health Department (Figure 26). If the woman is unsure about the screening she would like to receive, an additional consult can take place in the practitioner's room, after which she has to return to the registration desk to pay. When the CCS is performed, the medical professionals use their work phones to capture images. The images are subsequently labelled with a code followed by, for example, 'before', 'after VIA', 'after VILI', etc. When needed, DAMA provides the possibility to export patient files to Excel and PDF formats.

Implementing medical record numbers

As for the GICMED app, Electronic Medical Records (EMRs) appear to be a more appropriate starting point than EHRs, as they operate on a vast scale. However, EHRs might be interesting for the long term, to enable the app to work holistically and be usable not only for CCS, but also for breast cancer, family planning, etc. Further expansion to other departments in hospitals would then be a possibility as well.

GIC Space could make arrangements with the software engineers about how to compile the unique medical record number in order to identity a specific patient. Since a variety of numbering systems are used, establishing protocols is critical to avoid overlapping or multiple medical records as this can cause health problems and loss of the patients' medical history (Rediyantini et al., 2023).

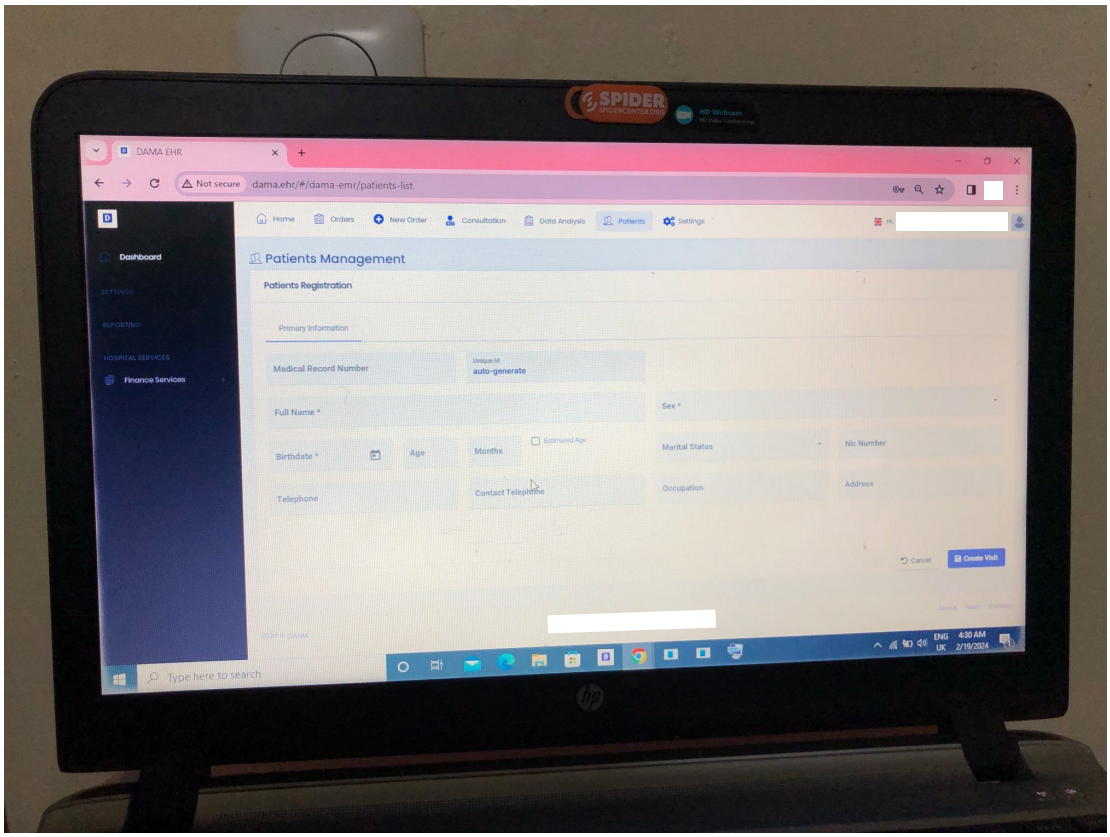


Figure 25: Photo of patients management screen in DAMA

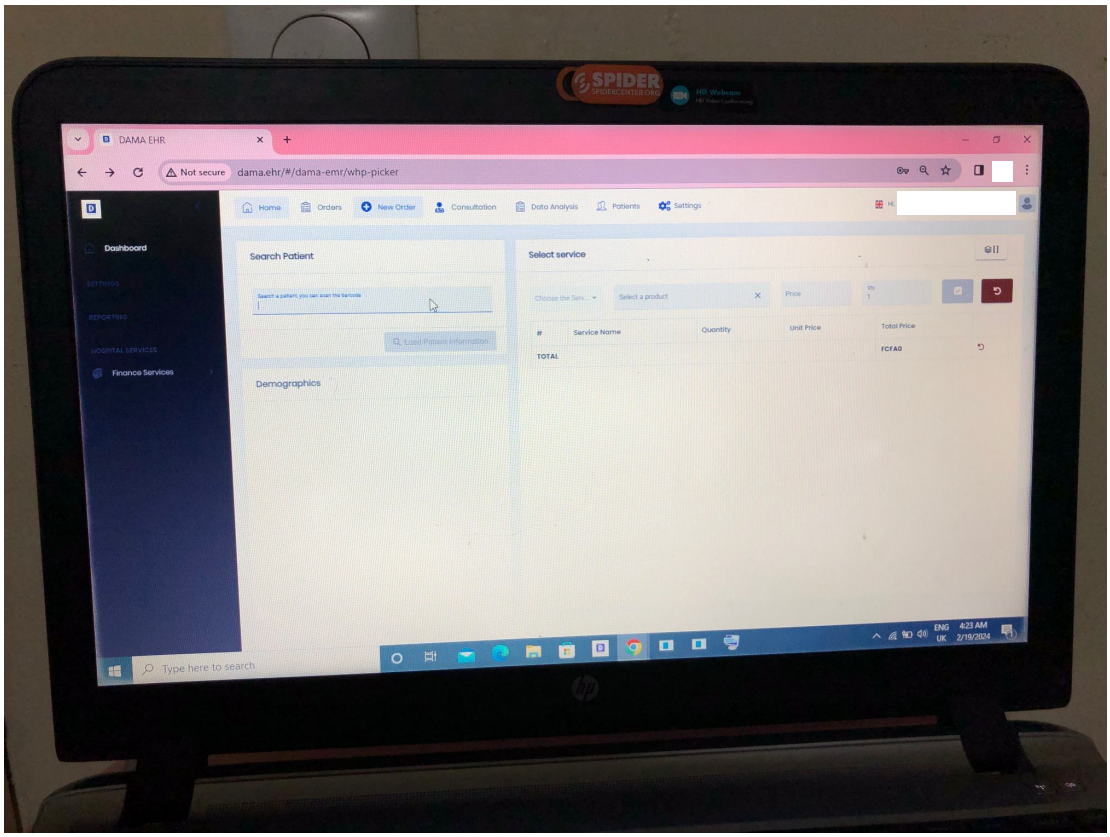


Figure 26: Photo of making a new order for a patient in DAMA

3.2.5 Desirable Features for Redesign

While delving into the benchmark analysis, several features emerged as highly desirable. These features will take the experience of the application to a higher level of satisfaction and should therefore be implemented.

What the GICMED app should offer

The possibility to:

- Capture high quality magnified pictures using autofocus.
- Add a (digital) green filter.
- Document cases in an EMR to review results and enable exchange of patient data between healthcare facilities. Interviews conducted in the field indicated that this will alleviate the workload for health workers and reduce loss of follow-up when a patient goes to another clinic that is out of the health facility's chain.
    - GIC Space could make arrangements and establish protocols with the software engineers working on DAMA, to compile the medical record number and avoid overlapping or multiple medical records.
- Enter findings that are required to reach a diagnosis, and fill in whatever else was observed on the cervix, such as an infection, other diseases or anomalies.
    - Attach explanatory notes of findings directly to photos, so other healthcare professionals can understand the thought process of the individual who completed the screening.
- Fill in a 'Management Plan', to establish whether biopsy, treatment or follow-up is needed.
- Share pictures and discuss the treatment plan with other colleagues or cervical cancer specialists when confronted with challenging or uncommon cases. This is particularly useful for less trained healthcare providers as it allows them to learn and become more proficient at making diagnoses.
- Trace a CCS back to the practitioner who executed it in case of follow-up or treatment.
- Export patient files
    - During an interview with a head nurse at CBC, the need for exporting images was expressed. Patients are occasionally referred after a CCS and if the woman can take the pictures made with her, it would save her additional costs and discomfort as a second screening would probably not be necessary. Furthermore, another reason why this functionality would be of great value, is that healthcare practitioners are obliged by the MOH to keep track of patient data and to transmit this to them (see chapter 2.1.1).

The suggestions made in this chapter for further enhancements of the app, fulfil essential needs or desires and have therefore been included in the design criteria in chapter 4.3.1.

3.3
Initial Detailed Design Proposal

While ideating on the functionalities the digital product should have, an initial version of the redesign was developed.

The redesign of the app should facilitate remote diagnostics and allow healthcare workers the ease of fulfilling all of their CCS needs, while being guided throughout the procedure. As described in chapter 1.2 Project Approach, with the implementation of AI, diagnoses will partly be automated. A new workflow for the app is therefore needed to support digital diagnoses, and this will allow GIC Space to gain competitive advantage. In order to achieve this, the following views should be implemented:

- **Login**: This will be the first screen presented to users. For privacy reasons, users will have to log in to get access to patient information and pictures.
- **Homepage**: The homepage serves as the focal point of the application, to which all views eventually return. This view should contain a list of all registered and screened patients, and should allow users to search for patients and export patient information.
- **Notifications**: The current GICMED app was designed to enable users to share cases with other colleagues or experts in the field, so they can give their opinion and diagnosis (Figure 27). The app should therefore send a message when a case is assigned to you or when someone else reviewed your case.
- **Patient Registration**: When the user intends to perform a CCS with a new patient, a number of questions will have to be answered in advance. This allows the practitioner to assess, which listed details might influence the (outcome of the) screening. The requested information will be based on the intake forms that are presently in use in CBC hospitals and on an evaluation session of the IRIS with three resident doctors.

Figure 27: Requirements for the GICMED application (GICMED, n.d.)

- **Images**: To direct the screenings procedure, two views will be needed. One for before capturing photos, to indicate the type of screening that will be done, and one for after to save pictures or to retake and delete them.

  For now, AI will only be trained on images. Compared to photos, videos have a much longer running time, because the algorithm has to run on each frame of the video. However, in the future it should be possible to make both photos and videos on which AI could run and form a diagnosis, since that is what Dr. Conrad prefers.

- **Making Pictures**: Because the agreement was made that the app should only be used during the screening to check and judge the quality of the pictures (chapter 2.1.3), there are no buttons located on this view, except one for going back to the previous screen.

- **Results**: As previously mentioned, AI algorithms will be incorporated to partly automate diagnoses. This means that the application will still rely on the user's judgement and that AI will solely serve as a second opinion. Users will therefore be asked to share their findings and opinion first, before AI hands over its conclusion. This will require two views, after which, if necessary, a colleague or specialist can be engaged for challenging cases to determine the diagnoses and management plan. Due to design directions 1 and 2 stated in section 2.2.2, potential ways of sending notifications to patients, in case of follow up or to stimulate them to undergo treatment, will have to be considered.

- **Export**: To support the need for exports as described in chapter 3.2.5, it was decided to enable export of 'Images', 'Patient Registration', as well as entire patient files. In addition, the head nurse at CBC and three resident doctors suggested to add the following features:
  - Like the IRIS, the redesign should facilitate exporting via email, Wi-Fi and a USB cable.
  - Bluetooth does not require an internet connection to connect devices. So, even in places without WiFi or cellular connection, such as LRS, this option can be beneficial.
  - Lastly, the head nurse would like to be able to print the results of the screening, to allow patients to bring them to another healthcare facility when they are referred. According to this nurse, printing will not be an issue in rural areas.

3.3.1 First Wireframes

The proposed views were translated into a first set of wireframes (Appendix B), which were gradually enhanced (see Chapter 4).

The wireframes were designed in such a way that they would align with two user scenarios:

1. For when it is the patient's first screening or when a new patient comes in to get a CCS, who might have done a CCS at another facility before, but was not registered in the GICMED system.
2. When the user gets a notification that their case was reviewed by another medical professional. The user will search for the diagnosis and assessment given and subsequently try to export that patient file.

4. CONCEPTUALISATION

A thorough inspection was made of the manner in which AI should be integrated. To understand how healthcare providers will interact with the application and which additional features the application should have, a User Flow Diagram was constructed. This chapter further clarifies the manner in which the final wireframes were built and evaluated, and ends by outlining the design criteria, the design decisions that led to the final design and the way the redesign is intended to be used.

4.1
Concept Development

At the beginning of the conceptualisation phase, it was decided to create one concept and gradually improve it throughout this design stage. The reason for this resolution is the GICMED app's complexity and wide range of potential features the app could implement in the future. Because of this and in order to bring the most value to users, it was chosen to iterate on the many possible functionalities and the way information should be presented.

4.1.1 The Redesigned Digital Flow

Figure 28 essentially shows the envisioned user journey for the redesign of the GICMED app with the final wireframes. The wireframes were designed in such a way that they would align with the two user scenarios mentioned in chapter 3.3.1.

In user scenario 1, after photos are taken there are two ways in which the options to fill in the results can be displayed. If the medical professional determines that the screening is inconclusive ('Result 1' in Figure 28), alternative options are provided than if the screening is considered conclusive ('Result 2.1' in Figure 28). This is because there is substantially less that has to be answered if the screening is deemed inconclusive.

The diagnosis formed by AI will only be communicated after the selection of conclusive and the completion of the assessment by the healthcare provider. This sequence of letting them fill in their own assessment before handing AI's result was deliberately chosen, since it obliges healthcare professionals to form their opinion first. Only then the app will allow the user to evaluate their decision-making against the verdict given by AI. If the order would be the other way around, there is a risk that AI's diagnosis will simply be adopted and this should be avoided.

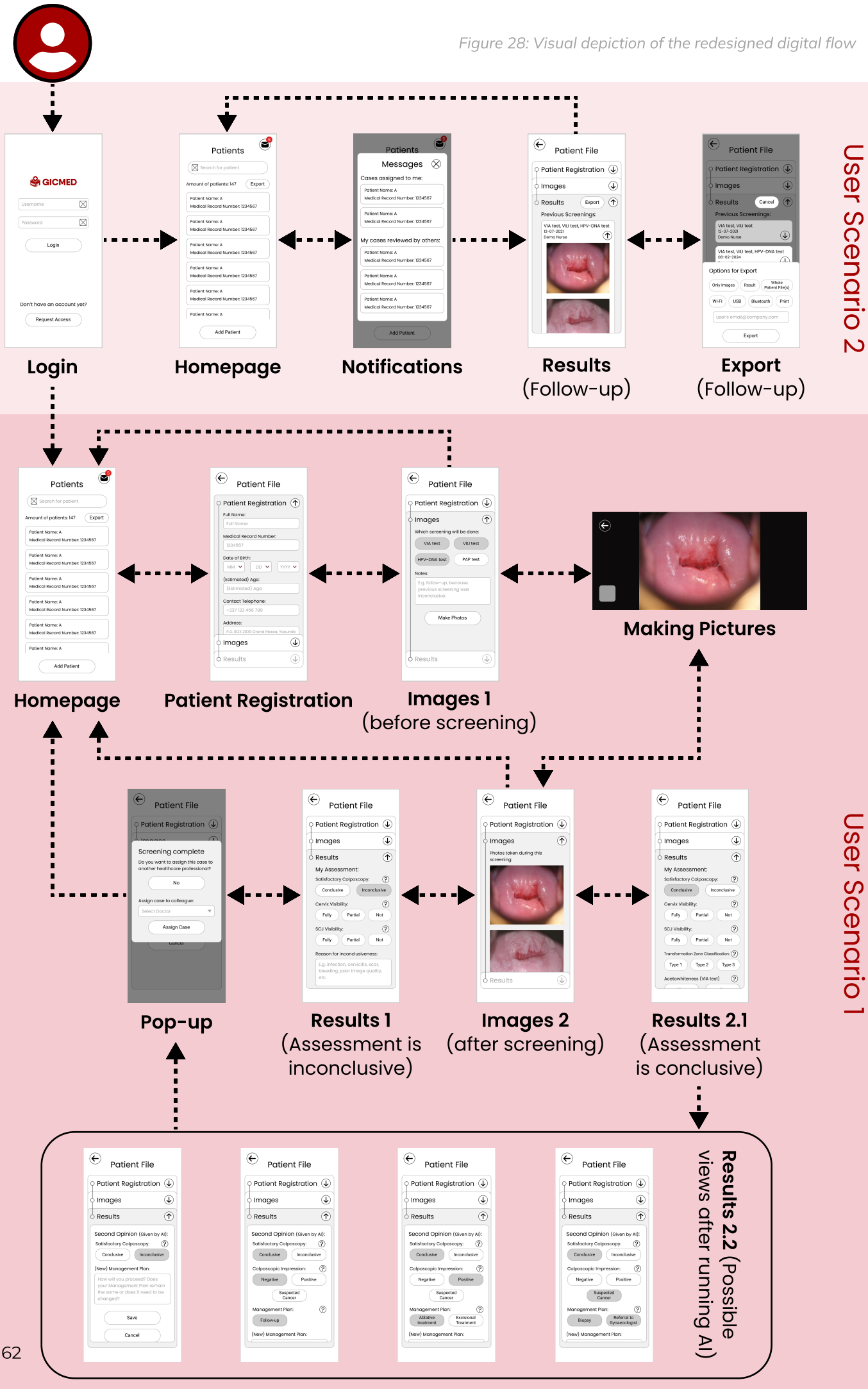
Long-term recommendation

According to Marijke, to maximise the sensitivity and thus reliability of the AI algorithms, they will have to be gradually implemented in the long term. The only algorithms that are currently being trained for the GICMED app, are trained by Marijke on photos of cervices on which VIA was performed. Nevertheless, to take into account all other potential AI deployments and outcomes the app may show in the future, four possible views were designed ('Result 2.2' in Figure 28).

Short-term implications

In the short term, AI only needs to run following the selection of conclusive in the 'Results' view ('Result 2.1' in Figure 28). This was concluded during a discussion with Marijke and Dr. Conrad, since it is not yet completely clear what the inconclusive group entails and therefore more researched needs to be done on how the algorithm should be trained. However, in the future, it would be ideal if assistance could also be provided for inconclusive cases.

Figure 28: Visual depiction of the redesigned digital flow



4.1.2 User Flow Diagram

Constructing a User Flow Diagram, helps to comprehend how healthcare providers will interact with the application, and it allows the digital product designer to map out the sequence of steps that have to be followed to accomplish a task or reach a goal.

As stated in chapter 2.2.2, the redesign of the application is based on the way CBC hospitals are generally structured. The constructed User Flow Diagram is accordingly based on this approach (see Figure 29), and not on the alternative scenario discussed in chapter 3.2.4, where the DAMA software system was introduced.

How to interpret the diagram

The User Flow Diagram should be read as follows:

The dark blue rectangular shape with rounded corners represents an action within the screening process.

The bright blue rectangular shape indicates the features the application should have.

The light grey rectangular shape stands for other possible steps within the screening procedure.

The diamond shape is used to indicate a decision that has to be made.

And arrows are used to connect the shapes and to symbolise the direction of the flow.

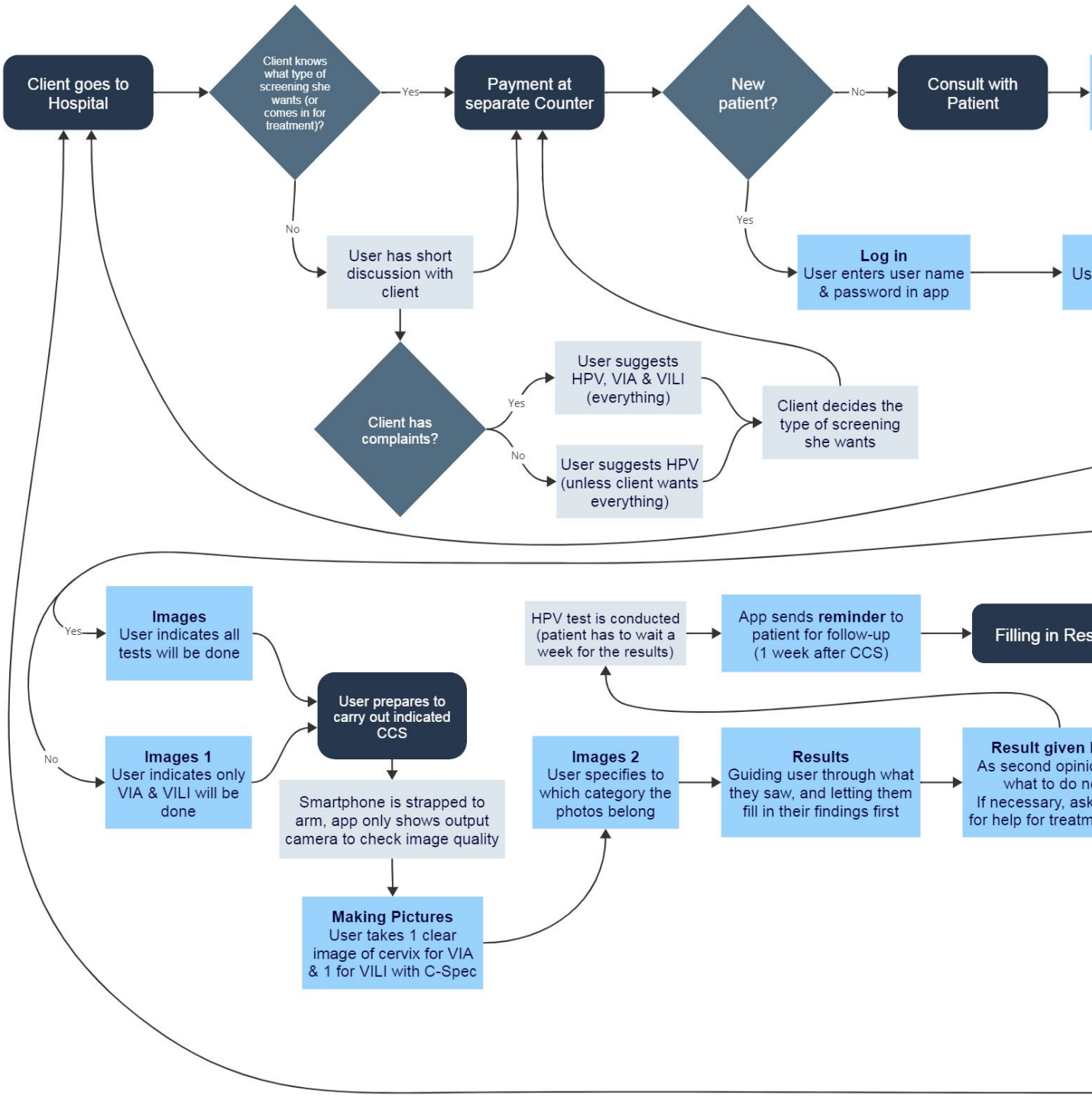
Clarification on notifications sent

The CBC nurses currently do not call patients for follow up for rescreening. However, they do call patients who need treatment, but did not return to the hospital. To adhere to design directions 1 and 2 (chapter 2.2.2.), the application should alleviate workload by assisting in notifying women who need to be reminded about follow-up or need to be stimulated to undergo treatment. The redesign will therefore automatically dispatch notifications to:

1. Remind patient of follow-up visit
2. Remind patient of rescreening
3. Express the importance and success of treatment

Several medical providers recommended to send reminders via WhatsApp, given that this communication platform, unlike email, is widely used in LRS.

Since HPV-DNA tests and PAP tests are rarely conducted in practice, the recommendations for sending reminders for rescreening after treatment, and when the colposcopic impression is negative are based on the VIA testing approach of the WHO (2021), see Figure 30. The other recommendations made on page 66 are drawn from findings in the field.


Client goes to Hospital
Client knows what type of screening she wants (or comes in for treatment)?
Yes
Payment at separate Counter
New patient?
No
Consult with Patient
No
User has short discussion with client
Yes
Log in
User enters user name & password in app
Client has complaints?
Yes
User suggests HPV, VIA & VILI (everything)
No
User suggests HPV (unless client wants everything)
Client decides the type of screening she wants
Yes
Images
User indicates all tests will be done
No
Images 1
User indicates only VIA & VILI will be done
User prepares to carry out indicated CCS
Smartphone is strapped to arm, app only shows output camera to check image quality
Making Pictures
User takes 1 clear image of cervix for VIA & 1 for VILI with C-Spec
Images 2
User specifies to which category the photos belong
Results
Guiding user through what they saw, and letting them fill in their findings first
HPV test is conducted (patient has to wait a week for the results)
App sends reminder to patient for follow-up (1 week after CCS)

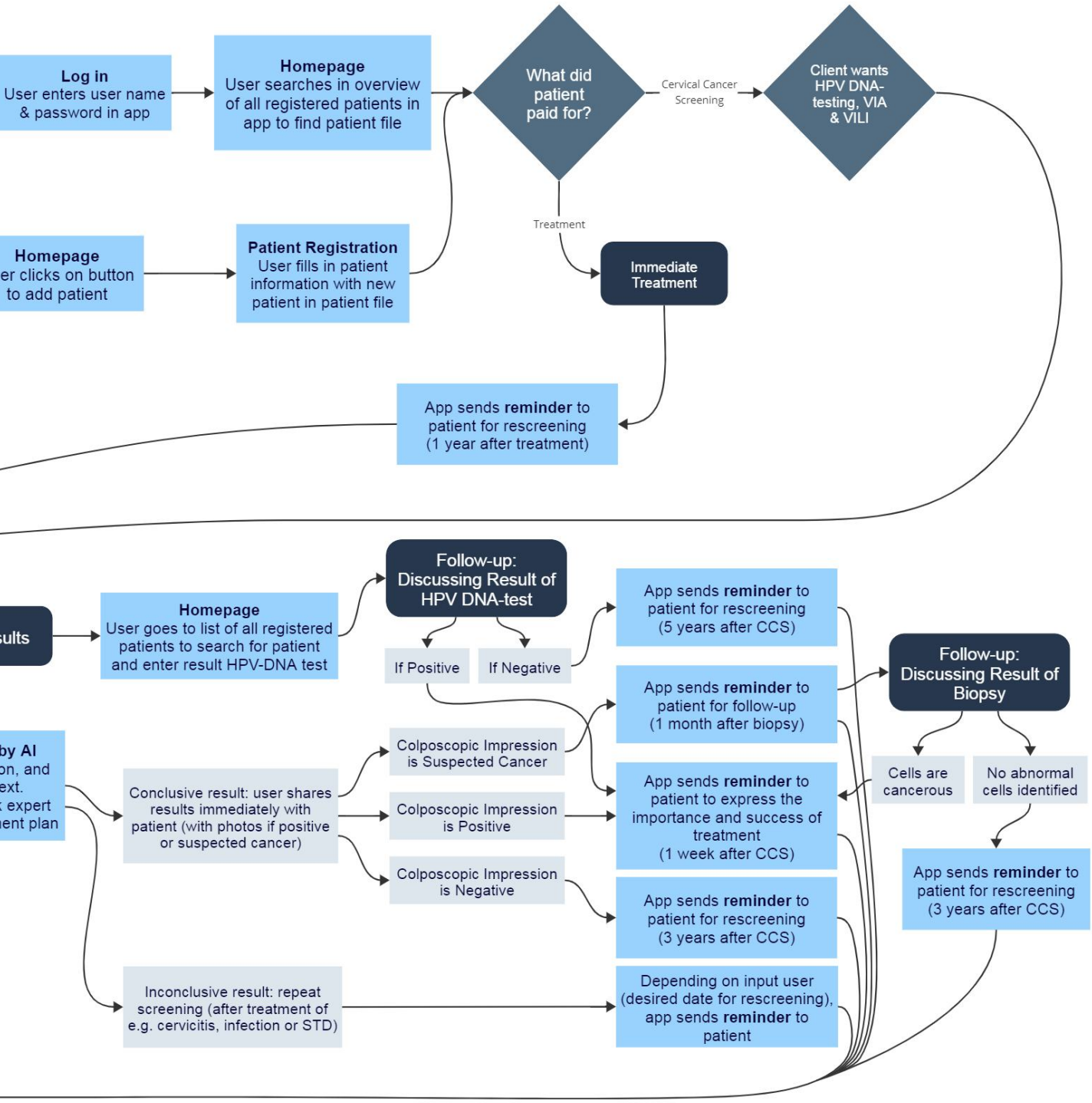


Figure 29: User Flow Diagram made in Miro

The timing of the notifications that should be sent, depends on the type of screening performed and its outcome:

- After discussing result of HPV DNA-test:
  - If negative, send reminder for follow-up 5 years after CCS. Based on the recommendation of the WHO (2021).
- Colposcopic impression is **Suspected Cancer**:
  - Biopsy is transferred to pathologist who sends analysis after a month by email to healthcare provider (depending on driver and location).
  - Reminder should therefore be send for follow-up, 1 month after biopsy.
- Colposcopic impression is **Positive**:
  - Send reminder to patient to express the importance and success of treatment, 1 week after CCS. Hopefully, patient gets treatment.
- **After treatment** was done:
  - Send reminder for rescreening, 1 year after treatment. Based on WHO guideline for VIA testing, see figure 30.
- Colposcopic impression is **Negative**:
  - Send reminder for rescreening, 3 years after CCS. This is recommended for both the general population of women and women living with HIV (WHO, 2021).
- Result is **Inconclusive**:
  The reason for a inconclusive result could vary and thus affect the date for the next screening. In this case, it would therefore be best to bring flexibility to sending reminders for rescreening, so the clinician is able to input a desired date based on the circumstances. This insight emerged during the evaluation of the final wireframes with Dr. Conrad (chapter 4.2).

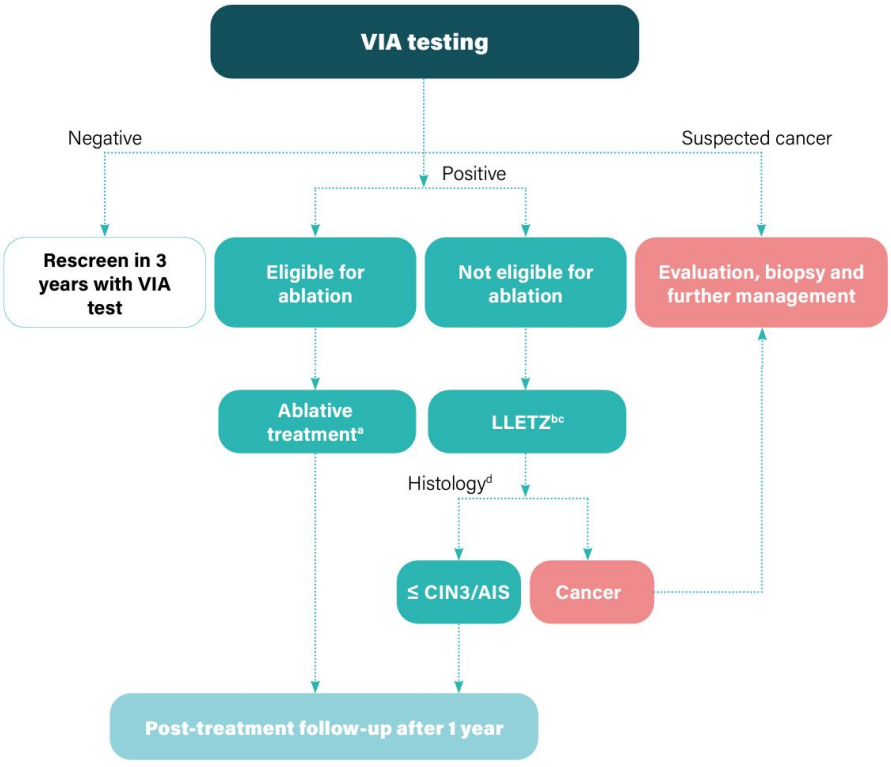


Figure 30: Primary VIA screening, screen-and-treat approach (WHO, 2021)

4.1.3 Final Wireframes

The black arrows in the final wireframes presented in this chapter, demonstrate how users will interact with the redesigned app.

Login

The first screen the user sees, is the login screen (Figure 31). On this view, the user can log in if access has already been granted by GIC Space and if not, one can request access.

Homepage

After logging in, the user arrives at the homepage. This is where users can view a list of all their registered patients, with the latest patient at the top of the list (as recommended by the resident doctors). This screen also enables the user to navigate to the notifications view, to export patient files and search for patients by typing in the patient's name or medical record number.

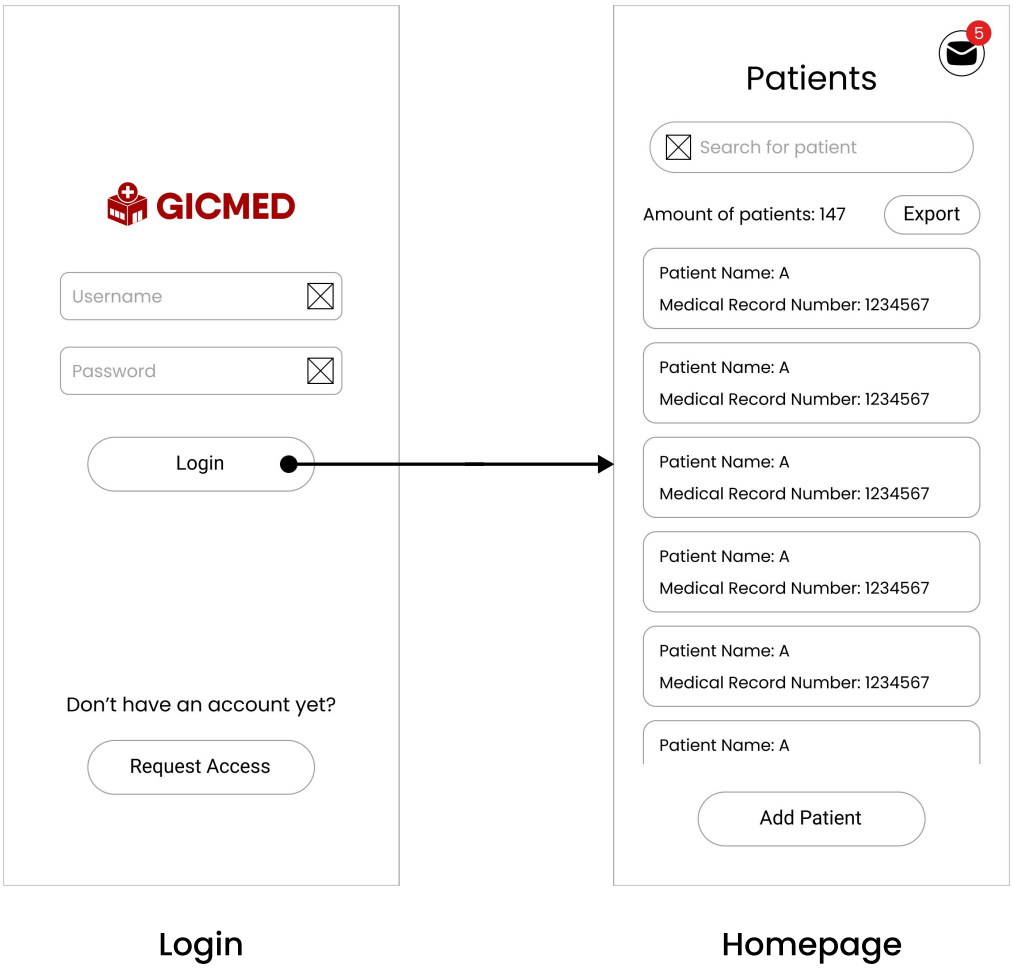


Figure 31: Final wireframes of the Login view and the Homepage

Patient Registration

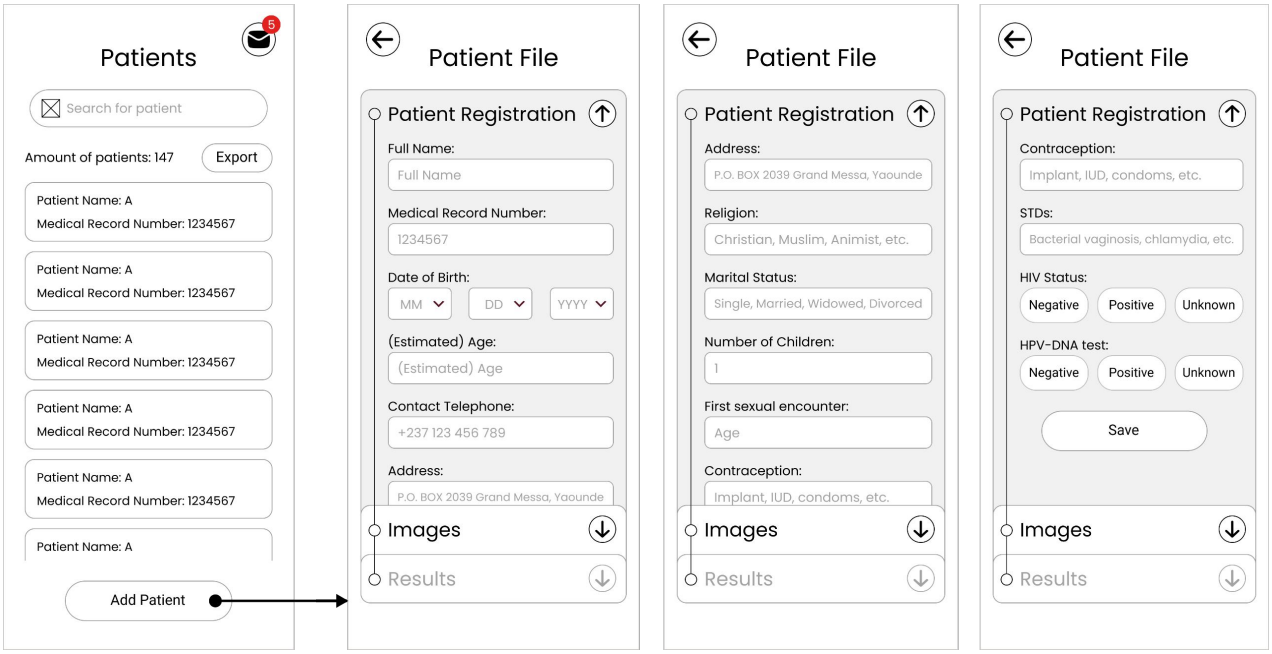
If a healthcare worker wants to screen a new patient, they have to click on the button 'Add Patient' on the homepage to be led to a new 'Patient File'. A 'Patient File' consists of three main components through which the user is guided: 'Patient Registration', 'Images' and 'Results'. The three 'Patient Registration' wireframes together in Figure 32, make up one scrollable view. All information requested within these frames has been validated with three resident doctors from Cameroon.

Full Name

There is a lot of flexibility in the naming structure in Cameroon. Awanto Josephine Nchang is an example of how some individuals originating from Cameroon, specifically Anglophone Cameroonians, use a distinctive sequencing in which they commence with a first surname, followed by a forename, and then a second surname. In contrast, Josephine Awanto Nchang is an example of how other Cameroonians start with a forename, followed by first and then second surnames (Kouega, 2007). That is the reason why the textbox merely requests the patient's full name and grants them the freedom to structure their name as it was given to them.

Medical Record Number

As recommended in section 3.2.5 Desirable features for redesign, medical record numbers have been implemented to enable exchange of patient data between health facilities and reduce the loss of follow-up when a patient goes to another clinic.



Homepage

Patient Registration
(these three wireframes together make up one view)

Figure 32: Final Wireframes of the Homepage and Patient Registration view

Date of Birth & (Estimated) Age:
Interviews with medical staff in Cameroon revealed that mainly in rural areas, parents do not always register their children when they are born. Residents from these regions, such as indigenous communities, tend to have many offspring whose birth dates are therefore sometimes forgotten. Hence, an additional textbox was included for age estimation of these patients.

Contact Telephone:
In Cameroon, the word 'phone' also has another meaning, since a phone could refer to a traditional leader. The wording 'Contact Phone' could thus be confusing and that is why 'Contact Telephone' was chosen.

Address:
There is a lack of street and place names and an absence of a precise and distinguishable address system in Cameroon (Njoh, 2010). Although this greatly complicates tracking patients, this textbox was recommended by the resident doctors, since it comes in handy when a patient gets lost for follow-up, especially during health campaigns. Community workers are part of the community where screenings are performed during health campaigns, and for that reason they can fairly easily find patients and encourage them to come in for follow-up.

Religion:
From interviews with nurses at CBC, it became clear that religion may influence the screening procedure. For instance, screenings conducted on Muslim women can only be performed by female medical practitioners and it is therefore relevant to include this textbox.

Marital Status:
Whether a women is single or with a partner becomes of interest once is established that treatment is needed. According to nurses at CBC, it very much depends on the partner whether money will be made available and whether he consents to the treatment.

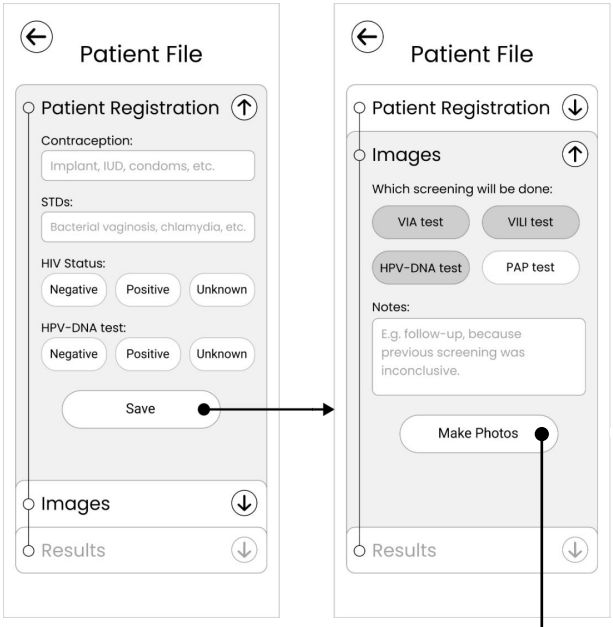
Number of Children, First sexual encounter & Contraception:
The three resident doctors advised to inquire about this information, because all three are associated with an increased probability of developing cervical cancer.

STDs:
In the event that a women reveals that she has a Sexually Transmittable Disease (STD) during the consultation, the medical professional may advise her that she, depending on the STD, needs to recover from it before having a CCS. After all, it could complicate the assessment of precancerous lesions and the screening could therefore be deemed inconclusive.

HIV Status & HPV-DNA test:
HIV and persistent infection with HPV also elevate the risk of developing cervical cancer. In fact, cervical cancer is six times more common amongst women diagnosed with HIV than amongst those without the virus (WHO, 2024).

Images 1

Once the user has provided all the required information for the ‘Patient Registration’, they can either save this data or cancel by returning to the homepage. If the ‘Save’ button is pressed, the app directs the user to the next section within the ‘Patient File’, which is ‘Images’ (Figure 33). On this view, one can indicate the type of screening that will be done and the app allows you to select multiple options. In the course of the field research, it was discovered that four types of CCS are offered in hospitals, namely: VIA tests, VILI tests, HPV-DNA tests and PAP tests. Although it is highly exceptional for a PAP test to be conducted due to its high cost, the decision was made with Dr. Conrad that the application should still support this option. The textbox for ‘Notes’ facilitates including more details about the scheduled CCS, for instance in case of follow-up.



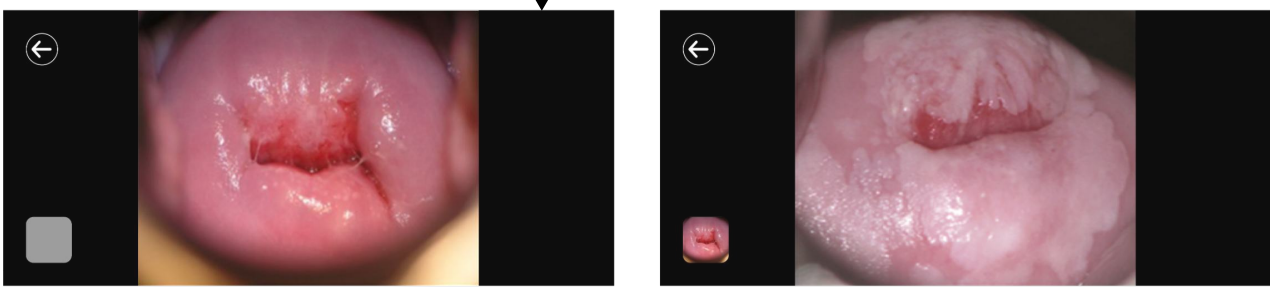
Patient Registration

Images 1

Making Pictures

Once the button ‘Make Photos’ is clicked, the user is led to the ‘Making Photos’ view. The healthcare provider will then set up to carry out the indicated CCS and will position the smartphone on the holder in landscape mode for greater camera visibility.

As stated before, the C-Spec will be entirely manually controlled during the procedure, and the smartphone can thus only be used to check and judge the quality of the pictures. When a photo is taken with the C-Spec, a confirmation of this action is given by the appearance of the captured image in the bottom-left corner of the screen.



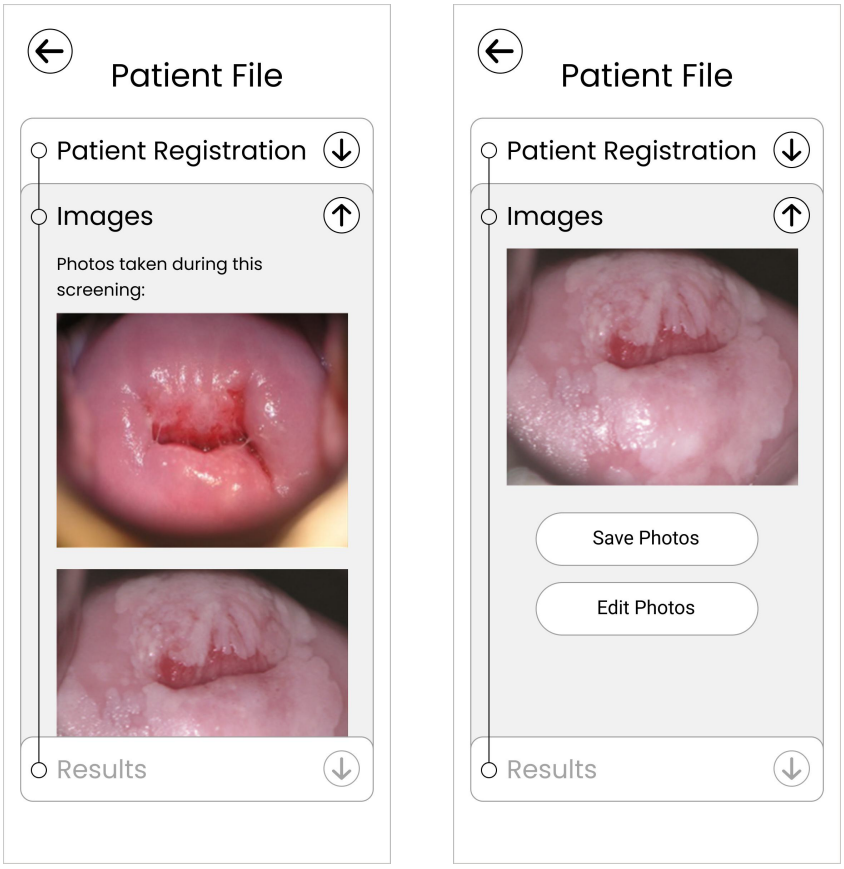
Making Pictures
(Cervix before and after VIA test)

Figure 33: Final Wireframes of the Patient Registration view, Images 1 view and Making Pictures view

Images 2

Based on what was specified beforehand, the app should allow a certain amount of photos to be taken. So, in case a VIA test and VILI test were selected, a maximum of two photos should be taken after which the application automatically proceeds to the 'Images 2' view in figure 34. This is the view where captured pictures can be reviewed and saved, and where one can decide to retake or delete photos using the 'Edit Photos' button. The 'Images 2' view is again in portrait mode, since once the CCS is completed and the hands are thoroughly sanitised, the screen can again be manually operated.

An evaluation of these wireframes with three AED students revealed that an indication is needed to clarify that the images can be enlarged when clicked. Karlson further indicated that although it would compromise the risk of contamination if was specified to which category the photos belong while screening (e.g. Cervix before, after VIA test, etc.), one could indicate this afterwards.



Images 2
(these two wireframes together make up one view)

Figure 34: Final Wireframes of the Images 2 view

Results 1

Once the photos have been saved, the user is directed to the final component within the ‘Patient File’, which is ‘Results’. As previously mentioned in this chapter, the options presented to the user change depending on whether conclusive or inconclusive is selected. So, the results view will either become ‘Result 1’ or ‘Results 2.1’ (see figure 35).

Cases are labelled as inconclusive if the cervix is not properly visible or if the outcome cannot be determined. As stated in chapter 4.1.2, the reason for a inconclusive result can vary, which is why a textbox is presented to provide a clarification. When the user’s assessment is saved, a pop-up appears to indicate that the cervical examination has been completed and to allow the user to transfer the case to someone else.

The date of when the screening took place, is automatically registered when the ‘Save’ button is pressed at the end of the results. This is essential for the software to identify when messages should be sent for follow-up. Depending on the type of screening specified in advance and the outcomes selected in the results view, reminders will be dispatched at the appropriate times (see User Flow Diagram in chapter 4.1.2).

Results 2.1

Conclusive means that the medical professional could clearly view the cervix and is sure that the result is either negative (normal cells of cervix), positive (abnormal cells detected) or suspected cervical cancer (more testing needed to determine if the cells are abnormal). As mentioned in chapter 3.2.2, all options provided by the IRIS to fill in the results were evaluated with 4 resident doctors. Of these options a couple were altered or simply implemented in the redesign. For instance, the classes for the Colposcopic Impression have been altered to 'Negative', 'Positive' and 'Susptected cancer' to align with the classes devised by Marijke. Based on the type of screening that was indicated in advance, in this case VIA and VILI, the ‘Results 2.1’ view will inquire about both Acetowhiteness (VIA) and Schiller Test (VILI). Miscellaneous findings were added to make the user think about other diseases that were visible during the examination. The nurses at CBC did not know all the possible findings shown on the wireframe, so by presenting these to them, they hopefully realise that checking for other diseases is important. A management plan is constructed based on the determined Colposcopic Impression and notes can be added to the findings to understand the thought process of the individual who completed the screening (as specified in chapter 3.2.5).

On Marijke's recommendation, ‘SCJ Visibility & Transformation Zone Classification’ will be replaced by ‘Transformation Zone Visibility’ to avoid confusion. This is because the ‘SCJ Visibility’ & ‘Transformation Zone Classification’ are difficult to determine with the naked eye, and the three different types (‘Type 1’, ‘Type 2’ & ‘Type 3’) are sometimes described as two types in literature.

Almost all elements on the ‘Result 1’ and ‘Result 2.1’ view are clickable to save time and enable the user to quickly communicate their findings. In addition, the screens are equipped with clickable question marks to provide further explanation when the meaning of certain terminology is unclear.

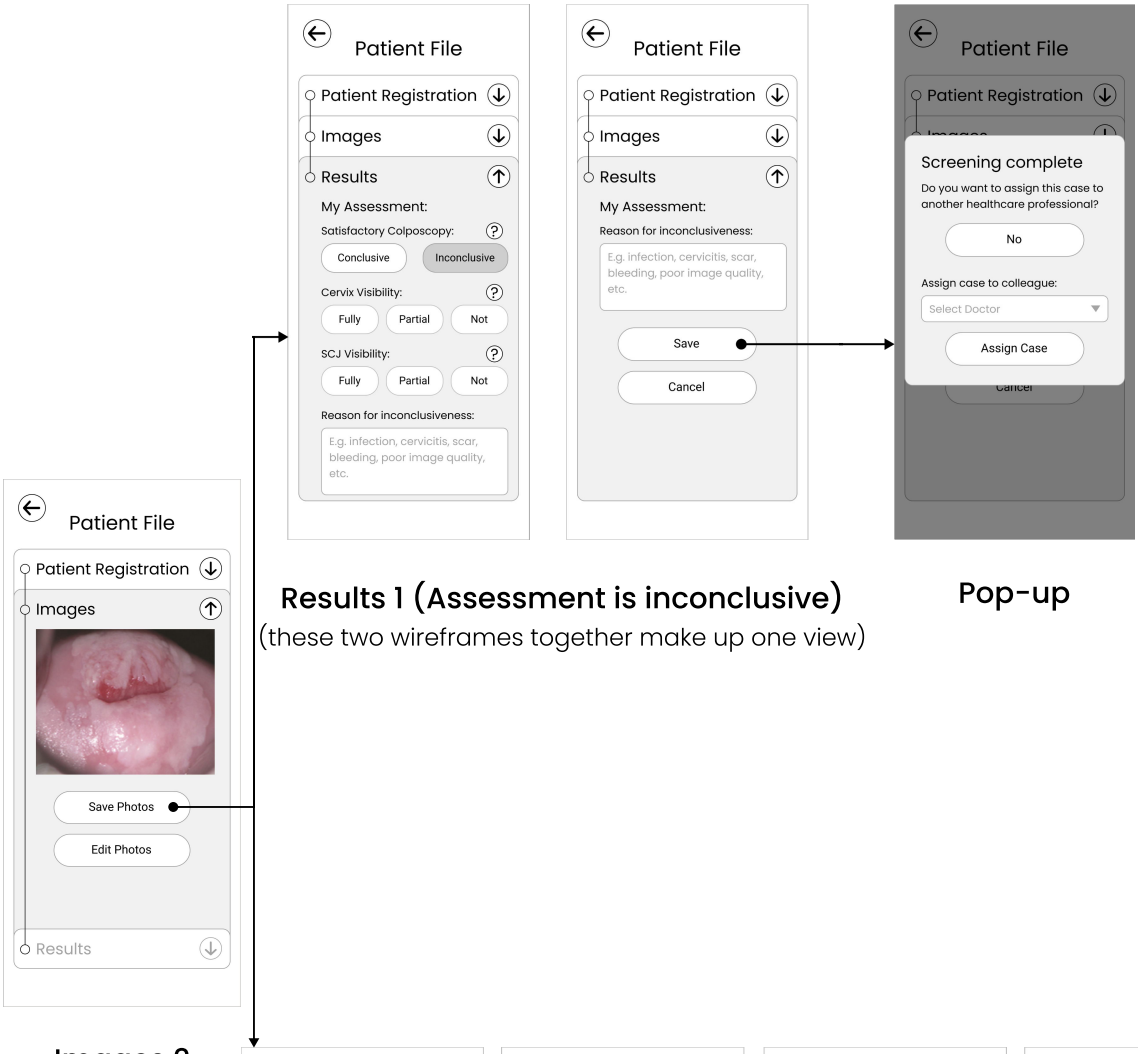
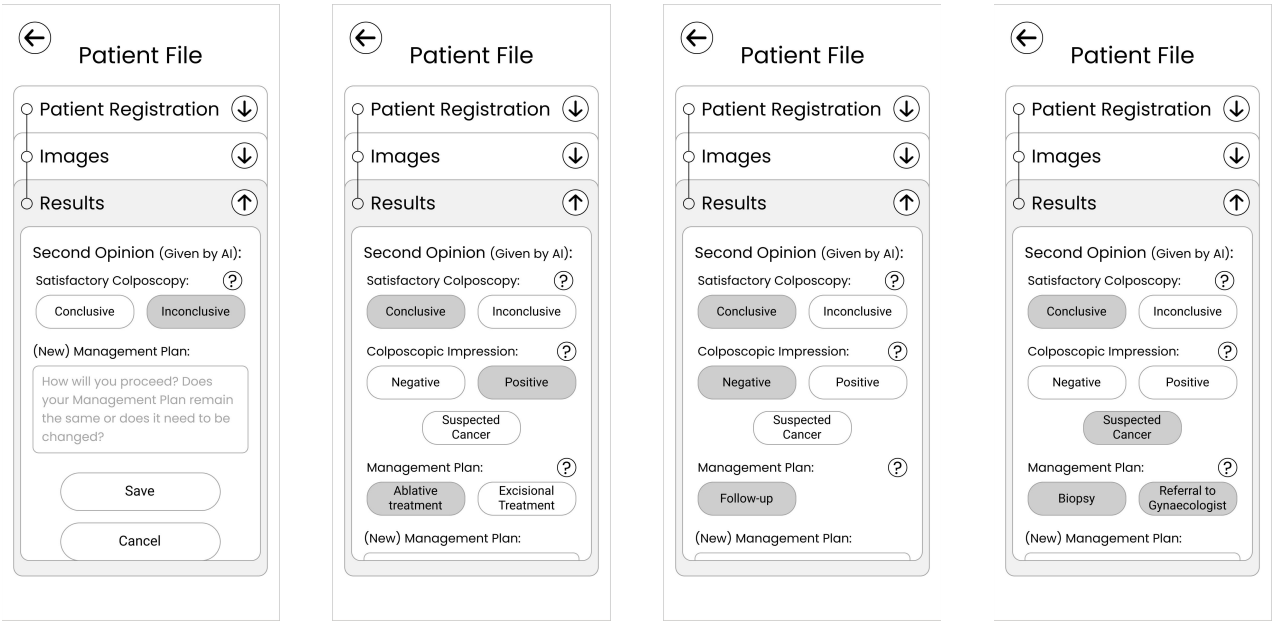


Figure 35: Final Wireframes of the Images 2 view and Results views

Results 2.2

When a conclusive case (‘Results 2.1’ view) has been saved, a second block within the results component automatically appears. This section contains a report generated by AI and is an assessment from the obtained images (‘Results 2.2’), which can be considered as a second opinion. There are four possible views the app could display after running the algorithms, see figure 36. This section has similar elements as the ‘Results 2.1’ view, although all information given by AI is already filled in based on its assessment. After the user has considered whether the (new) management plan should be modified, the ‘Results 2.2’ view can be saved. The same pop-up as in Figure 35 subsequently appears.

Marijke suggested to implement one more feature for the screen where the ‘Colposcopic Impression’ is positive. A delineation of the detected acetowhite lesion (obtained with the VIA test) could be presented by AI through a visual.



Results 2.2 (Possible views after running AI)

Figure 36: Final Wireframes of the Results 2.2 views

Notifications

When a case has been assigned to another doctor, the user will receive a notification when this case has been reviewed. These notifications can be found via a button on the Homepage (see Figure 37). The idea was to enable users to easily access the corresponding patient file via clickable messages. However, Karlson indicated that this could actually be confusing and that the 'cases assigned to me' might be better placed on the homepage with all the other patients. Hence, the Homepage and Notifications view had to be redesigned.

Results (Follow-up)

When the user has reached the Results view, previous CCS can be reviewed.

Since the case was assigned to another doctor, the 'Patient Registration' component should stayed closed for that person due to privacy reasons. Only the health worker that performed the screening is able to view the data of the patient, the captured images and the results.

The 'Results' view for follow-up contains the same information that what was indicated in 'Result 2.1'. This view does have some additions features, which can be found on the next page.

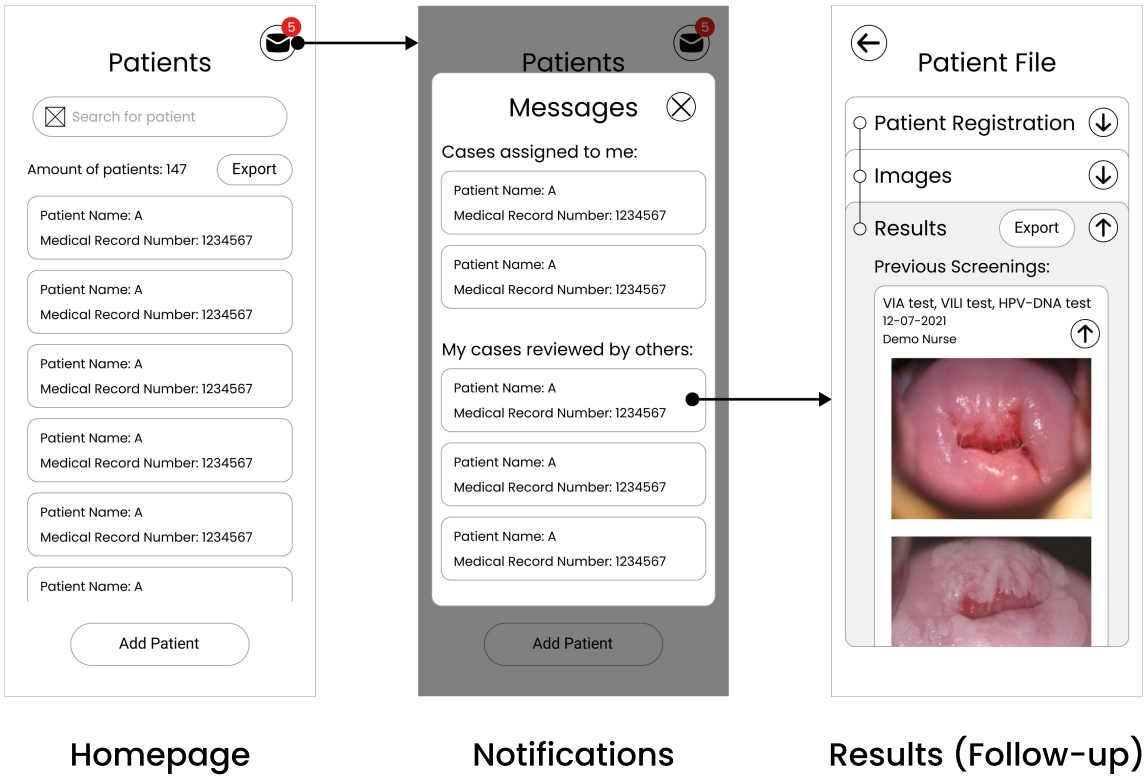


Figure 37: Final wireframes of the Homepage, Notifications view and Results view

Additional information

When the result of an HPV-DNA test, PAP test or biopsy arrives, the findings can be entered in the ‘Additional Information’ view (see Figure 38). Dr. Conrad shared that he likes the feature to mark the biopsy site, since a visual would be more accurate than the current system of saying e.g. 6 o’clock.

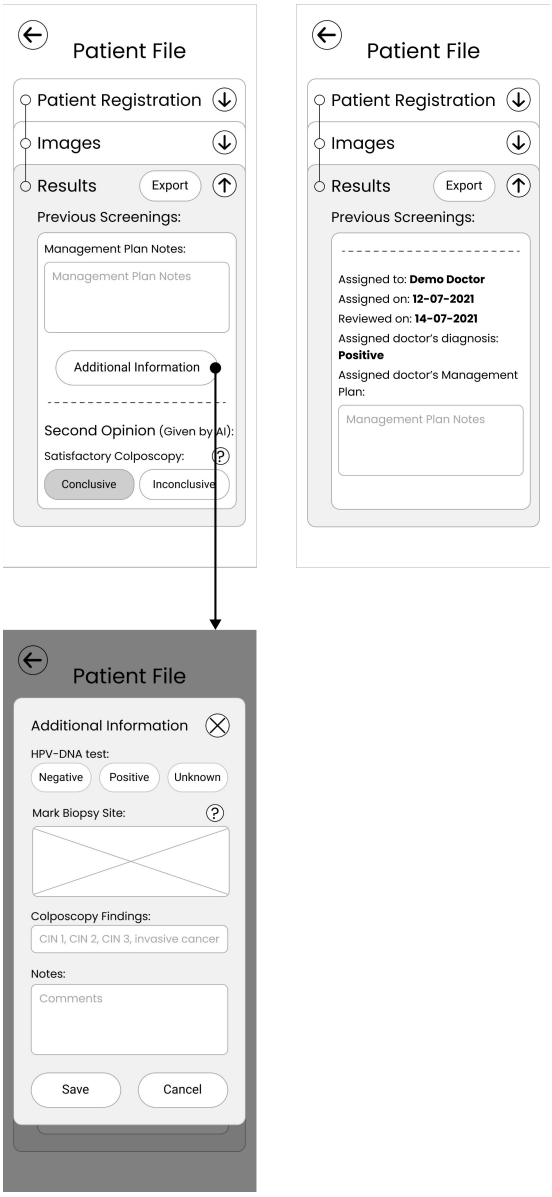


Figure 38: Final wireframes showing where additional information can be added

However, he would recommend to make it possible to draw on the cervix in stead of placing a pin, as the biopsy site tends to be fairly large.

It could be interesting to enable the pathologist to type the result of HPV-DNA tests and PAP smears, as it would relieve work for the medical professionals.

Dr. Conrad had been requested to provide a recommendation of how the results of a PAP smear should be displayed. He agreed with findings from literature that stated the result can be normal, abnormal or unsatisfactory.

At the end of the ‘Results for follow-up’ view is shown to who the case was assigned, on which date it was assigned and what that doctor’s diagnosis and management plan is. By clicking on the white frame within the Results component, the case can be resized to reveal other screenings of the patient (see Figure 39).

Export

As previously described in chapter 3.3, it should be possible to share 'Images', 'Patient Registration', as well as entire patient files. Exporting whole patient files allow users to quickly upload patient information to a computer and to transfer all data to the MOH. The Images are of particular interest to patients who are referred. However, a discussion with Dr. Conrad made clear that it could also be beneficial for the woman's partner. For instance, if a woman has a lesion on her cervix and needs treatment, and she has an image that she could bring home for her husband to see, he will probably have a better understanding of what cervical cancer is about and be more supportive towards her decease.

All other desirable options for exporting discussed in chapter 3.3, have been implemented. On the export view, it is possible to share one CCS or several of one patient. If the user want to export all registered patients, the user can simply go to the homepage where the entire patient list can be exported.

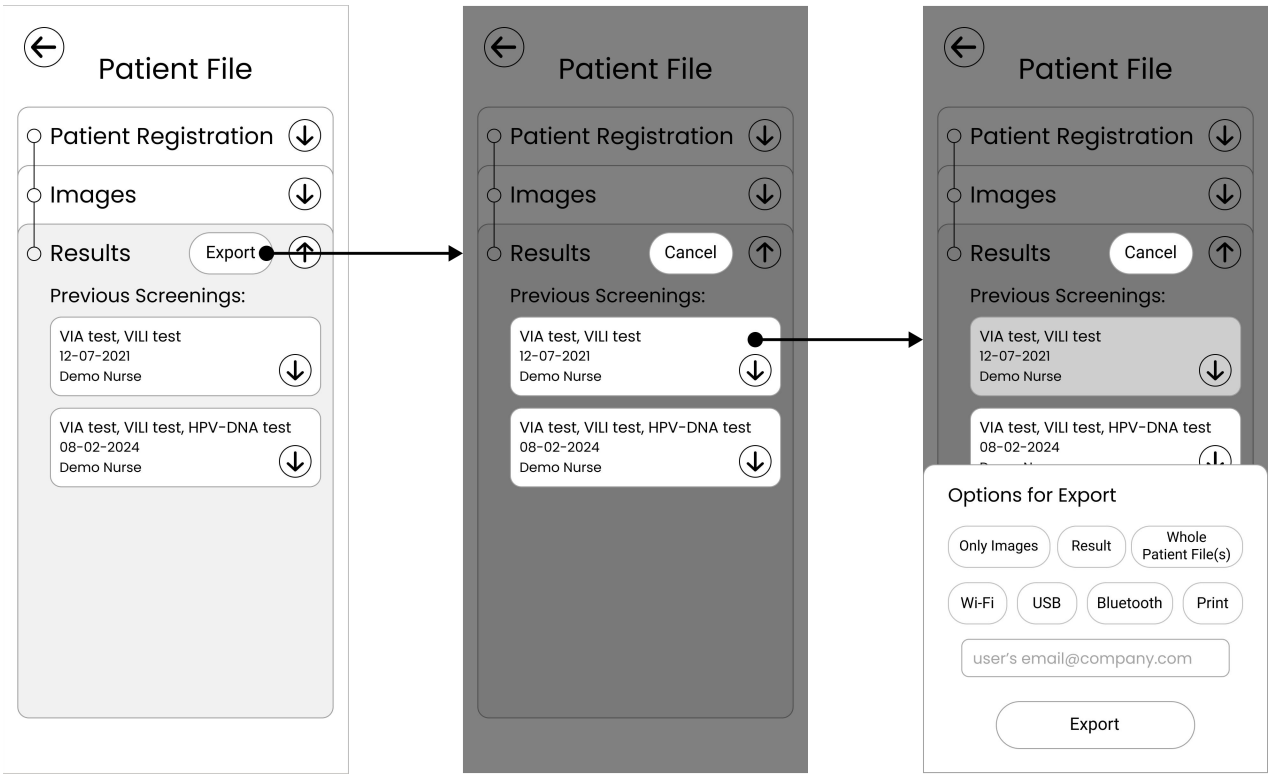


Figure 39: Final wireframes showing how patient files can be exported

4.2
Evaluation of Concept

The final wireframes have been assessed by Marijke (Figure 40), Dr. Conrad and Karlson. The evaluation with Marijke was carried out on paper and can be found in Appendix C.

The following points for improvement were identified:

1. For the Login, Karlson recommended to remove ‘Request Access’ as it not part of the flow.
2. The ‘Notifications’ view should not exist of clickable blocks.
3. On the ‘Images 2’ view, the user has to be able to specify to which category the photo belongs after screening (e.g. Cervix before, after VIA test, etc.).
4. In addition, an indication has to be added to clarify images can be enlarged when clicked.
5. Some terms on the ‘Results’ view need more clarification and the ‘SCJ Visibility & Transformation Zone Classification’ has to be replaced by ‘Transformation Zone Visibility’.
6. A visual of the delineation of the detected acetowhite lesion (generated by AI) should be added on the ‘Results 2.2’ view where the ‘Colposcopic Impression’ is positive.
7. On the ‘Additional Information’ view, it should be possible to draw on the image of the cervix in stead of placing a pin.
8. It has to be possible to select a desired date for rescreening on the ‘Results 1’ view, when the assessment is inconclusive.

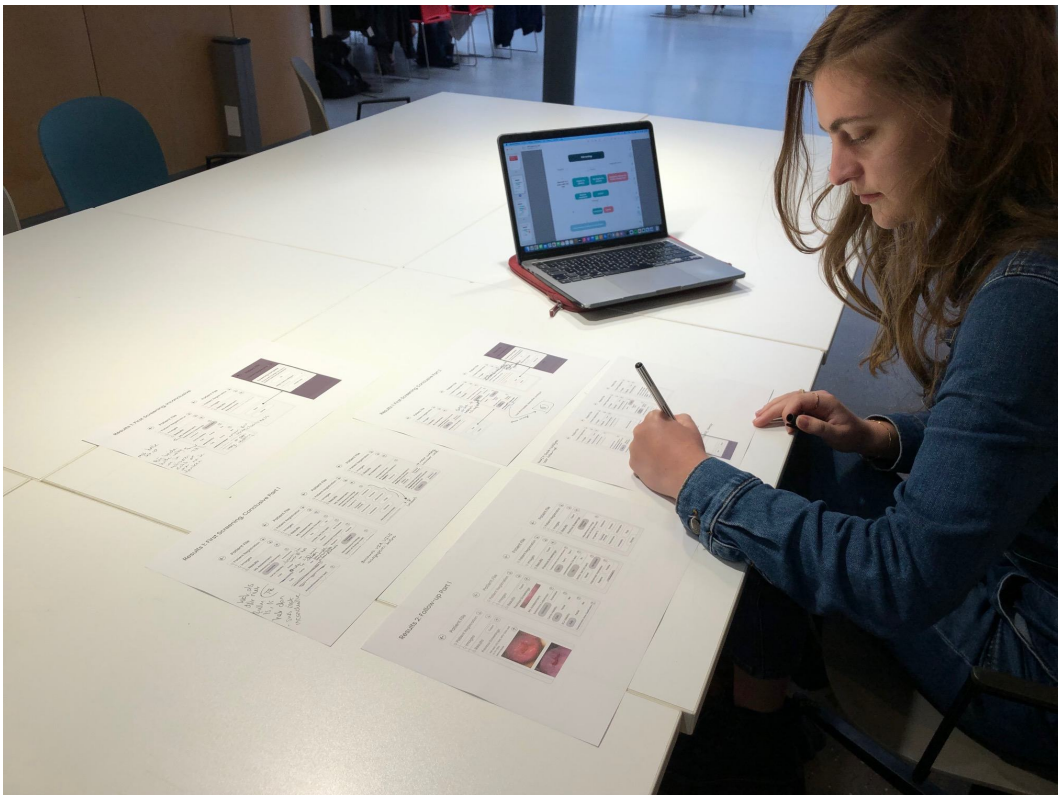


Figure 40: Assessment of final wireframes by Marijke Spijk

4.3
Final Design

The specific requirements identified throughout the design process, which the final design must meet, are called design criteria and are formulated in this chapter. The creation of the MVP using the software Figma and its intended use, is explained further.

4.3.1 Design Criteria

The desired features identified throughout the development of the redesign, have been translated into product criteria. Each criteria is accompanied with a reference to indicate where it was derived from.

1. The design of the application is intuitive (2.1.2 Usability Inspection).
   This means that the app can be used immediately and is easy to follow.
2. The design of the application is goal oriented (2.1.2 Usability Inspection).
   This means that the app guides the user to their end goal in a time-efficient and painless manner.
3. The application allows both user groups to devote more attention to patients and express empathy (User Journey Maps 1, 3 & 4).
   The app should ease and speed up the process of CCS, saving 5-10 minutes for each patient, as patient information only has to be filled in once in one spot.
4. The app helps healthcare providers to keep track of patient data more efficiently (User Journey Maps 1, 2, 3 & 4).
   a. The app notifies patients who need to be reminded about follow-up.
   b. The app stimulates women to undergo treatment.
5. The application offers the possibility to use AI as a second opinion in order to make a good diagnosis (1.2.1 Problem Definition).
6. The app can be used by both highly trained medical professionals, like general practitioners and gynaecologists, and less trained healthcare providers such as nurses and midwives (challenge set by GIC Space).
   The assumption has been made that healthcare personnel who have access to the app, are adequately trained and know the basics of how to perform CCS.
7. Cases are documented in an Electronic Medical Record (EMR) to review results and enable exchange of patient data between healthcare facilities (3.2.5 Desirable features for redesign).
8. Entering the ‘Patient Registration’ can be done offline (3.2.5 Desirable features for redesign).
9. The application is only used during the screening to check and judge the quality of the picture (2.1.3 Agreements on interaction with C-Spec).
10. The user can conduct the CCS independently (2.1.3 Agreements on interaction with C-Spec).
11. The application can capture photos for quality assurance (User Journey Map 3).
    This means that photos can be retrieved and inspected after screening.
12. The user is able to indicate the corresponding category (e.g. cervix before, after VIA test, etc.) for each picture made after the CCS (4.1.3 Final Wireframes).
13. Users have to fill in their findings and form an assessment before AI presents its outcome (4.1.1 The Redesigned Digital Flow).

14. The findings that have to be entered in the results component, are required to reach a diagnosis and also include whatever else was observed on the cervix, such as an infection, other diseases or anomalies (3.2.5 Desirable features for redesign).
15. Explanatory notes of findings can be directly attached to photos, so other healthcare professionals can understand the thought process of the individual who completed the screening (3.2.5 Desirable features for redesign).
16. In the results component of the application, clarifications have to be provided where needed (User Journey Map 3).
17. A 'Management Plan' has to be established to decide whether biopsy, treatment or follow-up is needed (3.2.5 Desirable features for redesign).
18. Cases can be assigned to another colleague or cervical cancer specialist, to share pictures and discuss the management plan (3.2.5 Desirable features for redesign).
19. The user has to receive a notification when a case has been assigned to them and when a case has been reviewed by a assigned doctor (3.2.5 Desirable features for redesign).
20. The user is able to search for and find patients in the patient file (3.2.5 Desirable features for redesign).
21. The diagnosis and management plan given by a assigned medical professional can be retrieved and viewed. (3.2.5 Desirable features for redesign).
22. Additional Information, such as test results, can be added to a case if needed (3.2.5 Desirable features for redesign).
23. The CCS can be traced back to the practitioner who performed it in case of follow-up or treatment (3.2.5 Desirable features for redesign).
24. Multiple options have to be provided for the export of images, patient details and entire patient files. (3.2.5 Desirable features for redesign).

4.3.2 Prototyping Approach

The final wireframes presented in chapter 4.1.3, needed to be developed into an interactive and, to the extent possible in Figma, working high fidelity prototype in order for it to be validated. With the software Figma, a collaborative online platform that facilitates the design of user interfaces, a MVP was built.

The final wireframes were designed in Figma in stages and according to the aforementioned user scenarios in chapter 3.3.1. Figma enables Digital Designers to develop a Design System that consists of all the colours, typography and components used within the design (see Figure 41 for the part of the Design System that contains all the components). A Design System makes it easier to apply elements to the digital prototype and update them when needed, and it assists in establishing visual consistency across all the views. Considering the restricted time frame, Figma is a optimal tool to construct the interactive high fidelity prototype without the need for extensive coding.

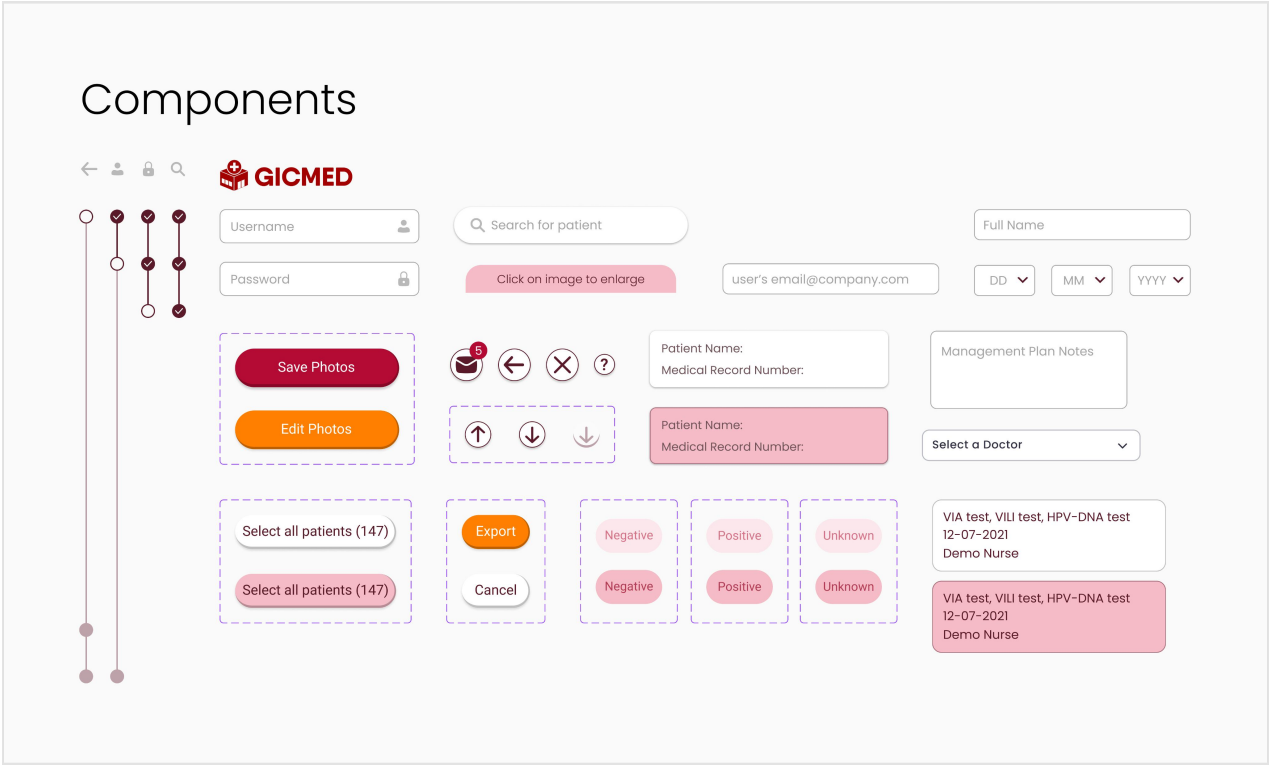


Figure 41: Part of the Design System in Figma

4.3.3 Minimum Viable Product

The new design (see Figure 42-45) will enhance the patient-caregiver interaction by allowing personnel to work in a efficient manner, leaving more time to provide care to patients. By assisting medical workers in keeping track of patient data, women who need to be reminded about follow-up or need to be stimulated to undergo treatment, will be notified.

With the redesigned application, healthcare workers will hopefully have more pleasure in their work and it might even reduce depressions, which will greatly benefit their employers as well. The workload for the Data Manager will be considerably reduced, as this individual will only have to check if the data in the 'Patient Files' are correct and occasionally liaise with the Data Supervisor if mistakes are uncovered.

The introduction of an EMR will greatly simplify the management of patient data. Moreover, the many options provided to export data, eases the process of submitting this information to the MOH, who can in turn improve healthcare services.

Since patients will receive reminders for follow-up and get encouraged to seek treatment, there will hopefully be less loss of follow-up, more women screened and more treatment provided when necessary. This could facilitate the fulfilling of the three targets set by the WHO to turn cervical cancer into a preventable disease.

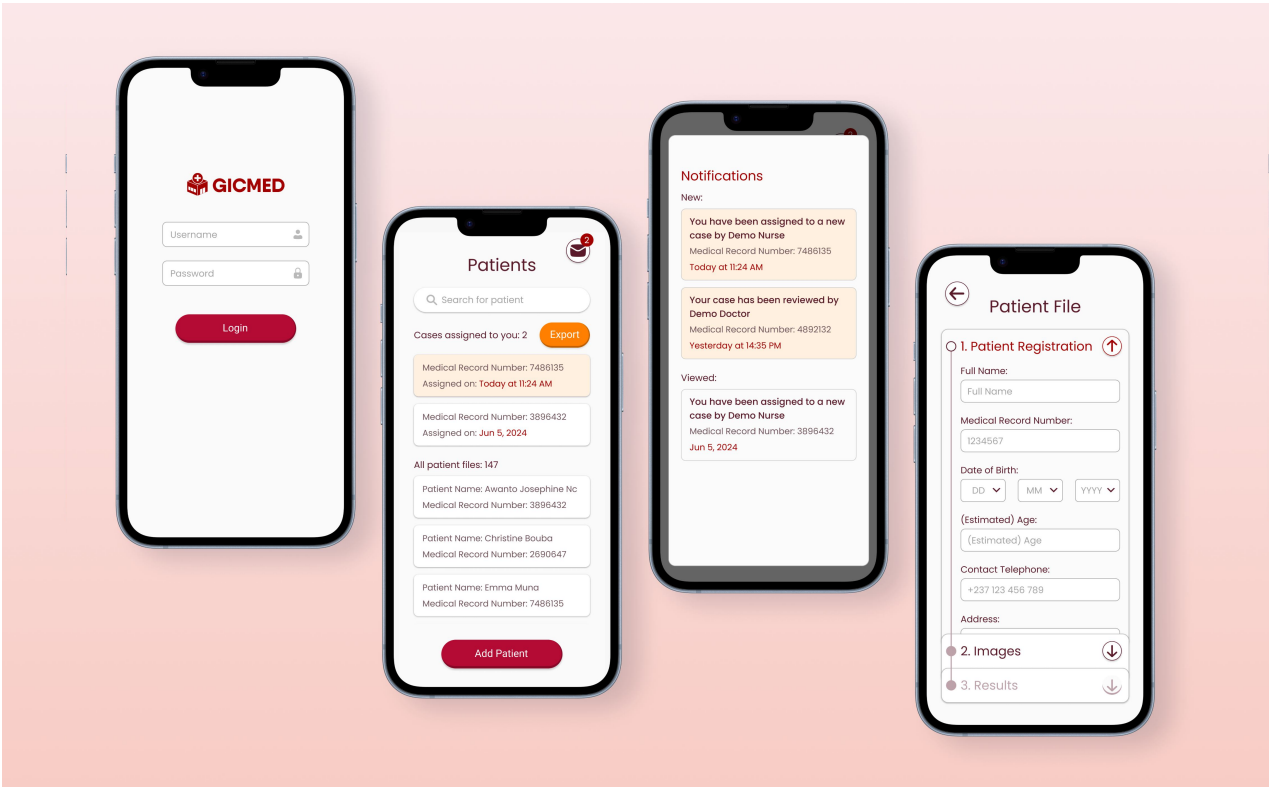


Figure 42: Final Design (1)

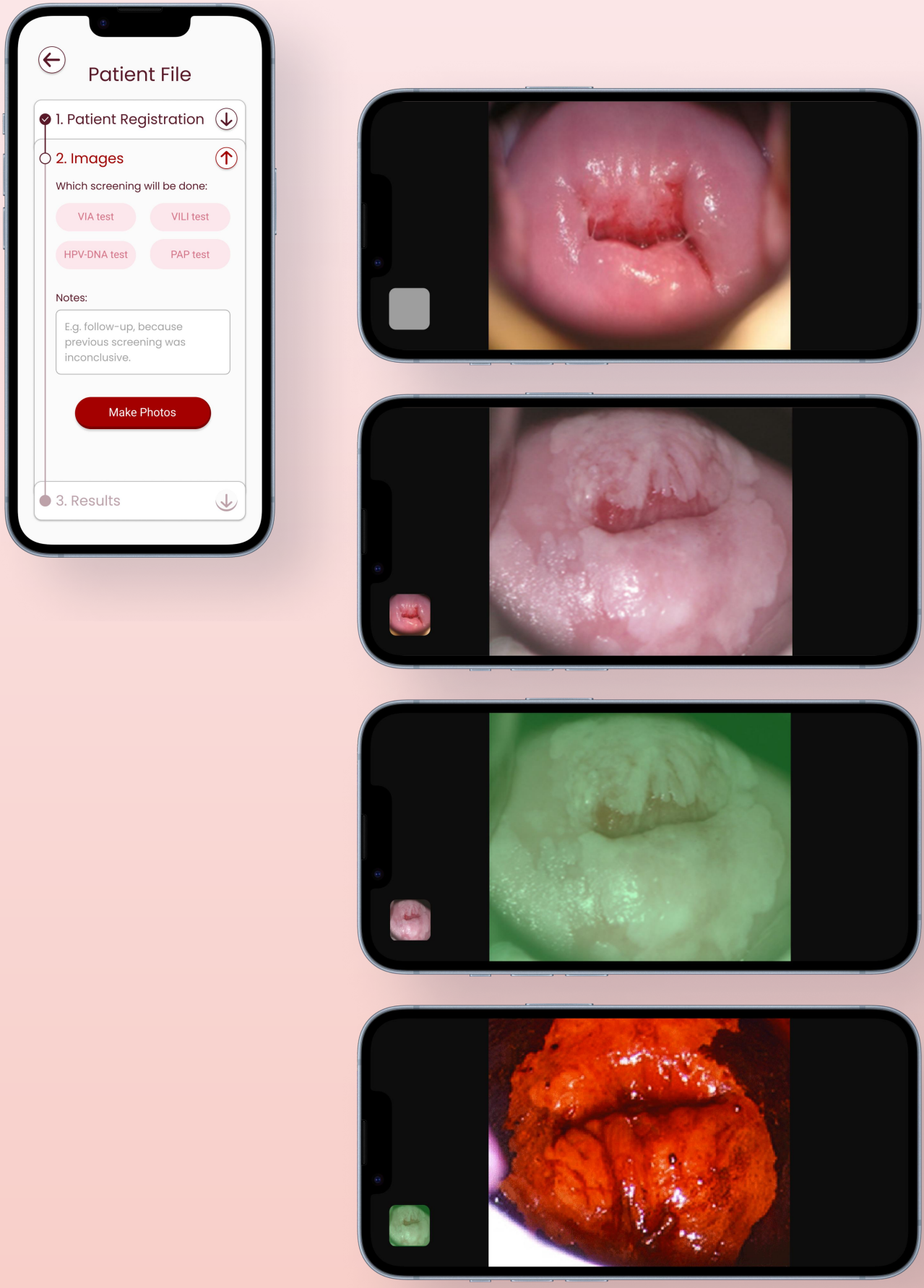


Figure 43: Final Design (2)

An indication was added to clarify that the images can be enlarged when clicked (see chapter 4.2 point 4).

Users now need to specify to which category the photo belongs after screening (see chapter 4.2 point 3).

Additional information on symptomatology has been added (see chapter 4.2 point 5).

In the ‘Results’ section, when scrolled down, the delineation of the detected acetowhite lesion makes it appear as if AI justifies it's decision (see chapter 4.2 point 6).

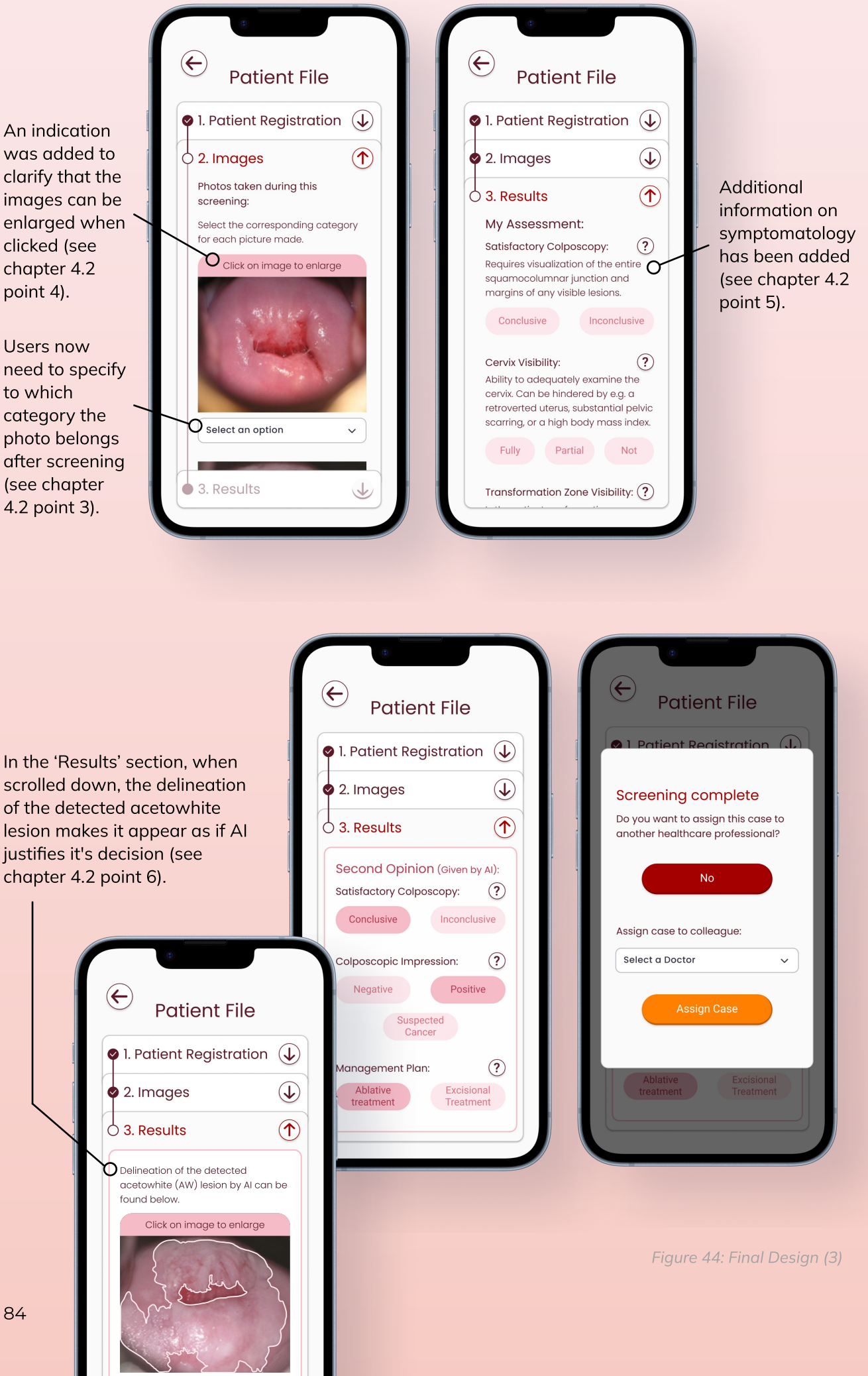
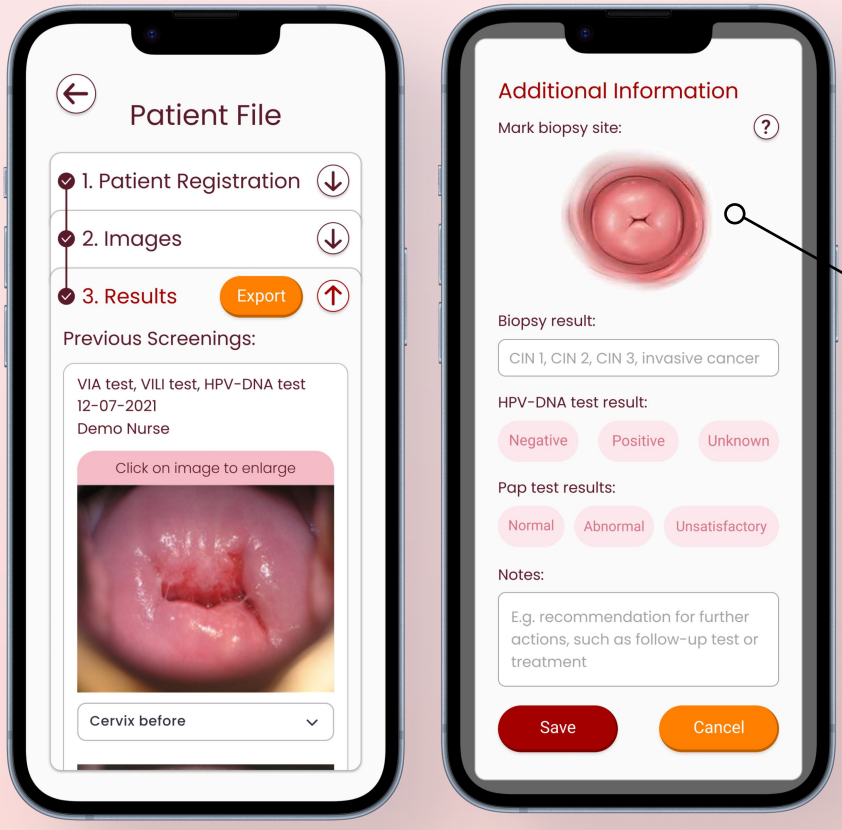


Figure 44: Final Design (3)

Additional Screens For User Scenario 2



The possibility was added to draw on the image of the cervix to mark the biopsy site (see chapter 4.2 point 7). In the future, more options should be provided for drawing and erasing.

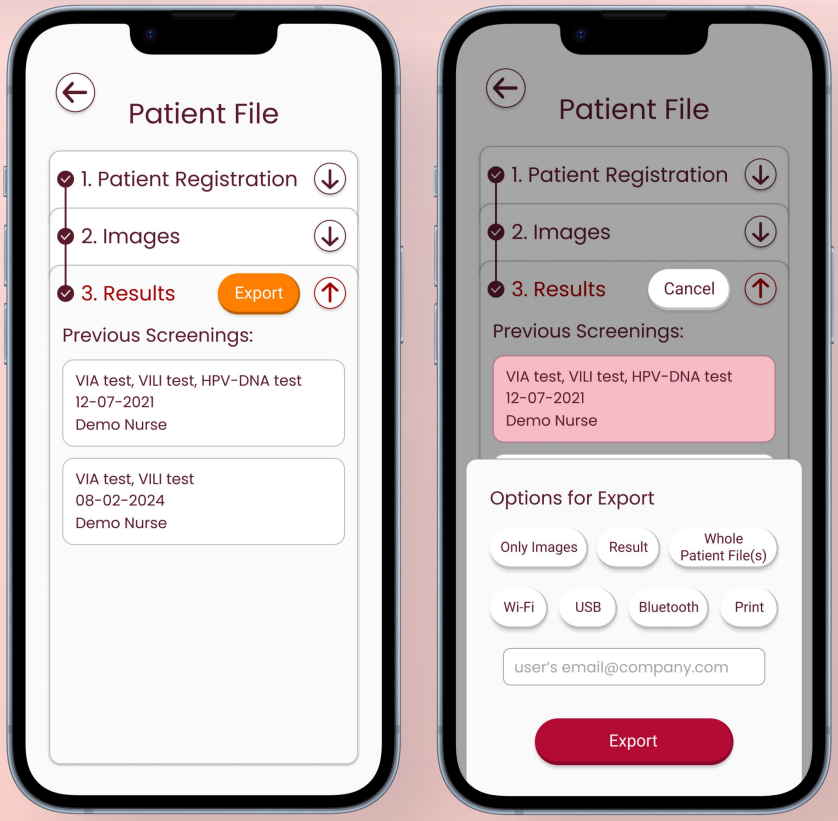


Figure 45: Final Design (4)

4.3.4 Intended Use

The intended interaction with the redesigned application during the whole CCS procedure, is visualised according to user scenario 1 & 2 (see Figure 46 & 47).

The app will be actively used during the consultation with the patient and during the result delivery. The screen will purely be a display while the client is screened to avoid contamination.

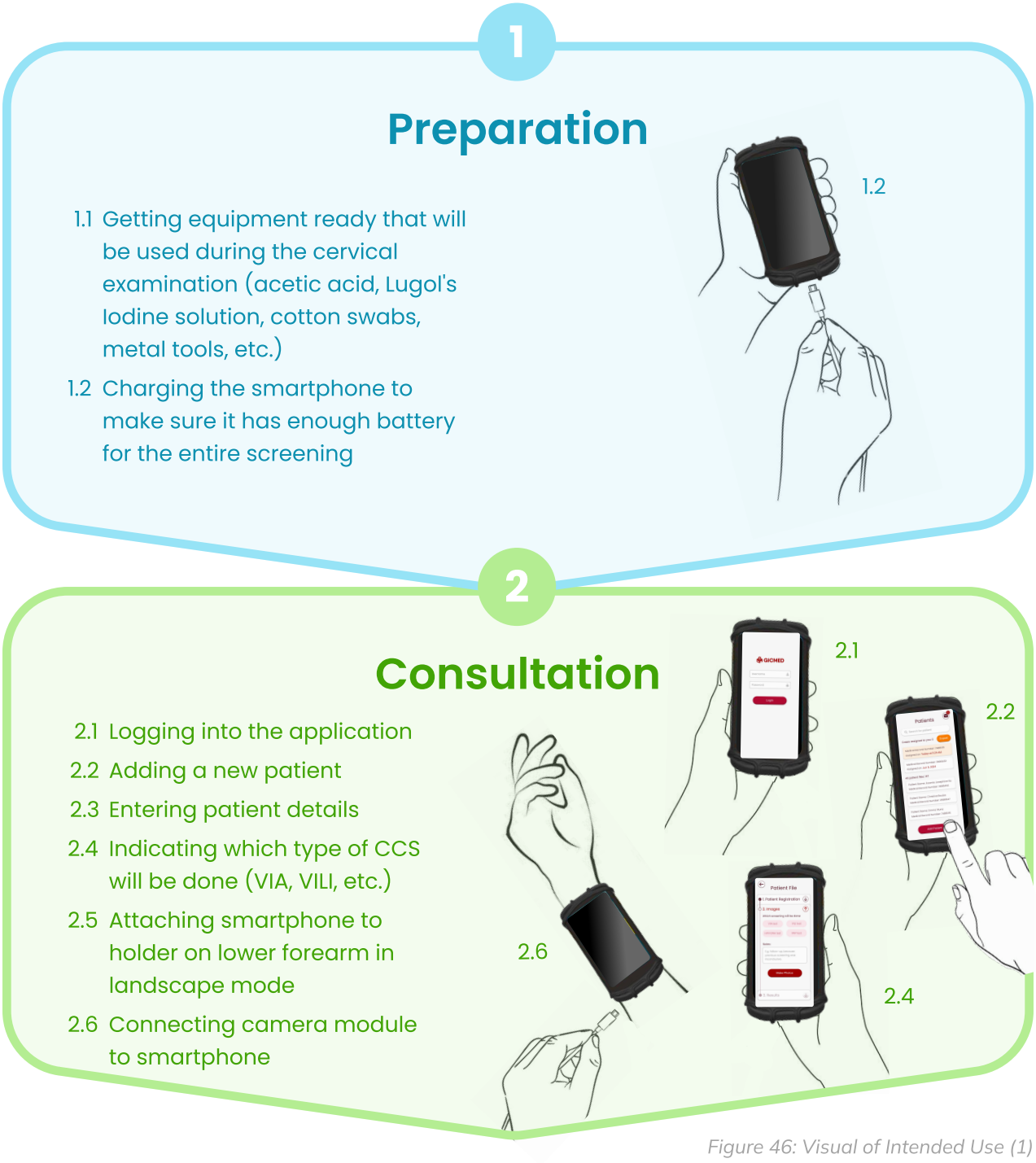
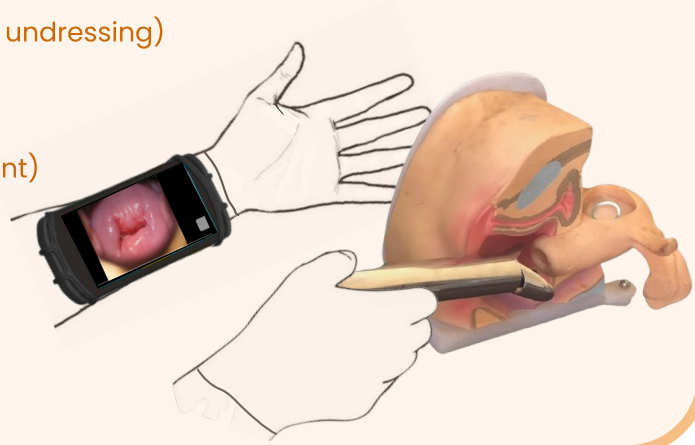


Figure 46: Visual of Intended Use (1)

3

Screening Client

3.1 Washing hands (while patient is undressing)
3.2 Putting on medical gloves
3.3 Preparing the C-Spec (Applying silicone sheath, applying lubricant)
3.4 Inserting the C-Spec
3.5 Viewing output camera while capturing high quality images with the C-Spec
3.6 Excerting the C-Spec



4

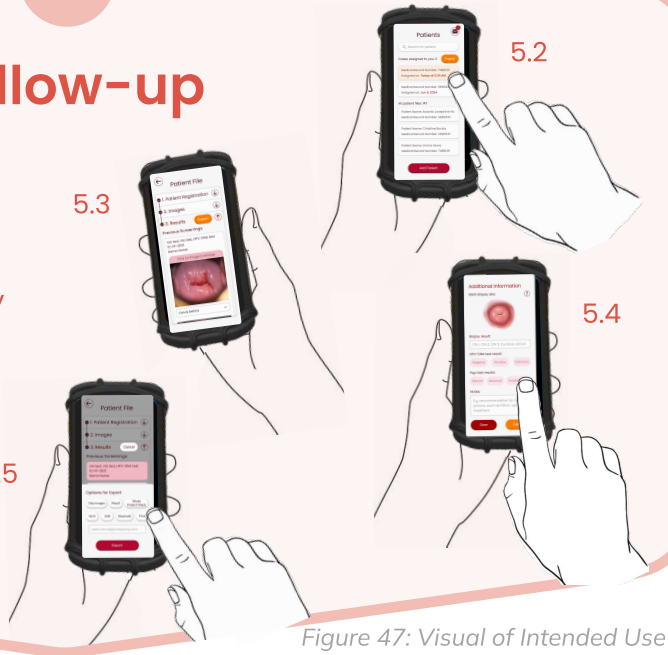
Result Delivery

4.1 Throwing away disposables (while patient is getting dressed)
4.2 Disinfecting the C-Spec
4.3 Indicating to which category the photos belong (e.g. Cervix before, after VIA test, etc.)
4.4 Documenting findings of CCS and adding notes
4.5 Second opinion provided by AI
4.6 Assigning case to another doctor

5

Follow-up

5.1 Receiving notification (case reviewed by assigned doctor)
5.2 Searching for patient file
5.3 Searching for diagnose given by assigned doctor in patient file
5.4 (If needed) adding additional Information
5.5 Exporting patient file



User Scenario 2

Figure 47: Visual of Intended Use (2)

5. EVALUATION INTERACTIVE PROTOTYPE

An evaluation study was planned to assess the final design with potential users, and to determine to what extent the redesign would meet the design criteria. The procedure of the user tests, the manner in which data was collected and the analysis of the findings are explained.

5.1
Evaluation Plan

To establish a test plan for the redesigned high fidelity prototype, certain objectives were defined. Furthermore, testable targets were formulated in order to test the design criteria (see chapter 4.3.1) and measure the quality of use of the redesigned application.

5.1.1 Evaluation Goals

The plan was to assess the high fidelity prototype by means of user testing, and the MVP was to be deployed at a designated CBC facility to evaluate its capabilities.

The objectives of the user tests were:

- Obtaining insights regarding how potential users experience and interact with the redesigned application.
- Getting perspectives on whether AI would be trusted and utilised by potential users.
- Gathering recommendations for further improvements.

5.1.2 Testable Targets

The defined testable targets align with user scenario 1 and assist in determining if the redesign is successful. Due to limited opportunities for testing and time constraints, this particular scenario was chosen to be assessed as it could provide GIC Space with a competitive advantage (see chapter 3.3).

The following targets have been set:

1. a. The application can be used immediately (**Design Criteria 1**).
   b. The application is easy to follow (**Design Criteria 1**).
2. a. The application guides the user to their end goal in a time-efficient manner (**Design Criteria 2**).
   b. The application guides the user to their end goal in a painless manner (**Design Criteria 2**).
3. a. The application eases the process of CCS (**Design Criteria 3**).
   b. The application saves 5-10 minutes for each patient (**Design Criteria 3**).
4. a. The user trusts the result given by AI to determine the diagnosis and management plan (**Design Criteria 5**).
   b. The user makes use of both the result given by AI and their own knowledge and experience to come to a diagnosis and management plan (**Design Criteria 5**).
5. The design communicates in the same level of knowledge that both user groups have (**Design Criteria 6**).
6. The application is only used during the screening to check and judge the quality of the picture (**Design Criteria 9**).
7. The user can conduct the CCS independently (**Design Criteria 10**).
8. The user selects the corresponding category (e.g. cervix before, after VIA test, etc.) for each picture made after the CCS (**Design Criteria 12**).
9. The user fills in their findings and forms an assessment before AI presents its outcome (**Design Criteria 13**).
10. Enough clarifications are provided in the results component of the application (**Design Criteria 16**).
11. The user establishes a ‘Management Plan’ to determine whether biopsy, treatment or follow-up is needed (**Design Criteria 17**).

5.2
User Test Procedure

In order to manage the user tests, participants had to conduct tasks according to an imaginary scenario. The specifications of the user tests, how they were conducted with the interactive prototype and with which participants, are described in this chapter.

5.2.1 Scenario and Tasks

To achieve the aforementioned objectives in section 5.1.1, a scenario was invented to support the subjects in performing specific tasks. The scenario is a situation the participant could normally encounter when working at the Women's Health Department and is about a new patient who will receive a CCS for the first time. The tasks that have to be conducted start once the imaginary patient has entered the examination room for the consultation.

The tasks are tailored to the capabilities of the interactive prototype. For instance, Figma does not allow you to generate a type interaction in the prototype, since this would require more coding. As a result, all textboxes have already been completed, leaving the participant with the possibility of simply checking the boxes.

The sessions were divided into three sections:

1. Introduction (<5 minutes). Both the C-Spec and digital prototype are introduced, and information about the user tests is provided.
2. User Scenario (± 15 min). The participant is asked about their previous experience with digital colposcopes, after which instructions are given for the test. The subject is guided through the test by means of the scenario and by executing five tasks with the prototype. Meanwhile, the subject is requested to explain what they are seeing, thinking and doing.
3. Post-test Questions (± 15 min). Once the tasks are completed, the participant is asked to make an evaluation using custom Likert scales and open-ended questions. For the custom Likert scales, participants are requested to indicate their experience of performing the tasks on a scale from 1 (strongly disagree) to 5 (strongly agree). This method is commonly employed in visualisation evaluations to obtain quantitative estimations of subjective attributes, for instance, for the ease of use (South et al., 2022).

5.2.2 Pilot

To ensure testing would proceed smoothly and nothing would be overlooked, a pilot test was done with the head nurse of the CBC facility where the user tests would be conducted. The following improvements were made after the pilot:

- More clarification was needed in the introduction section to explain both the device (the C-Spec) and the redesigned application, and how they are intended to be used together in the future.
- Although it would have been ideal if the high-fidelity prototype would be displayed on their own work phone, it was difficult to monitor online what the participant was doing. The decision was therefore made to let participants share the screen of their laptop to display and interact with the prototype there.
- Regarding the tasks, it became clear that the terms in the app should not be used to avoid giving hints.

- Lastly, the use of a dummy patient seemed redundant as all textboxes were already filled in.

5.2.3 Setup

The interface is still a work in progress and not all functionalities could be made operational without additional coding. The tested prototype was therefore not completely functional and the participants had to be made aware of this limitation.

The tests were conducted online via Zoom. The participants in Cameroon were asked to share their screen on which the interactive prototype was displayed, to observe how they executed the tasks. In order to let the individuals who were not testing continue working, each subject was requested to move to a specific room where everything was set up for the test. Afterwards, the participant was kindly instructed to place all the materials back to how they were initially positioned. In this relatively secluded room, the circumstances in which the tests were conducted could be maintained. The location was fairly quiet with few distractions, and a table, chair, laptop and examination table were present. Only the participant and moderator were present in the room while testing. The responsibility of the moderator was to observe, make notes and manage the prototype to make sure it was functioning properly.

The C-Spec was introduced to the subjects for them to simulate the future interaction between the app and the device. A smartphone holder was provided to place their work phone on their arm and visualise the interaction during the screening procedure. The participants were requested to think aloud during the test and explain what they were doing and thinking, to follow their actions and obtain their understanding of the prototype.

5.2.4 Participants

The recruitment of potential participants already took place during the field research while interviewing and observing nurses in a particular CBC facility. The individuals were recruited based on the following requirements:

- The participant works in a health facility and has at least a beginner level experience in performing CCS in LRS.
- This person is familiar with the use of digital colposcopes.

The three nurses with whom the user tests were conducted, met these requirements. These participants can be considered as potential users of the application and can be regarded as less trained healthcare providers. The necessary consent forms for the user tests had already been filled in on site. The template of the consent form can be found in Appendix A.

5.3
Results & Analysis

Both qualitative and quantitative data was gathered to analyse the implications of the design decisions made, and to conclude which aspects or features need to be enhanced. The analysis was conducted by inspecting the level of difficulty experienced per task, carrying out a boxplot analysis and and addressing responses to open-ended questions.

5.3.1 Data collection

The user tests were both qualitative (by means of observations and interviews with open-ended questions) and quantitive (by means of custom Likert scales) in nature. The combination of both qualitative and quantitative data would ensure better accuracy and validity of the results. Participants could share remarks about their experiences both throughout and after the study to foster an open conversation and to identify issues.

A template was prepared to capture the participants' remarks, actions and feedback, such as which buttons were pressed and the level of difficulty experienced. This data was gathered while the five tasks were being executed and after the study (see Appendix D for the filled in templates).

5.3.2 Analysis

Each of the five tasks were reviewed in terms of difficulty experienced by the participants on a level of: 'No difficulty', 'Some difficulty' and 'Significant difficulty' (see Figure 48).

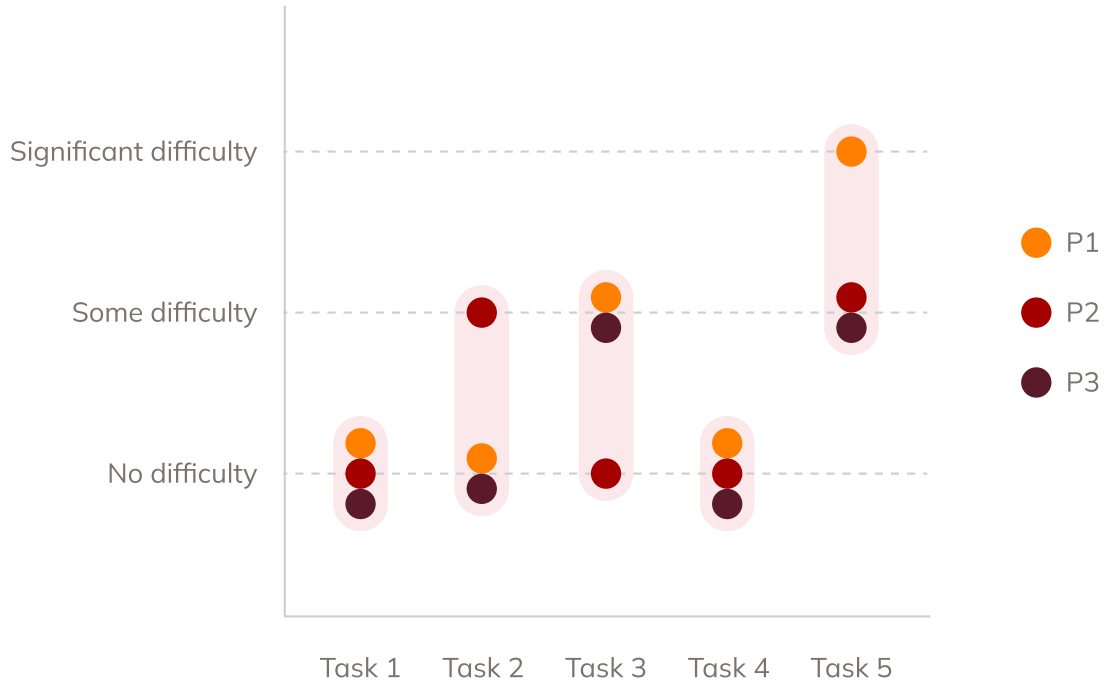


Figure 48: Graph of the level of difficulty experienced per task

The tasks were formulated as follow:

- Task 1: Please register the new patient in the mobile application. This patient is HIV negative and has never done an HPV-DNA test.
- Task 2: Please indicate that VIA and VILI will be performed, but do not yet
- Task 3: You can now take photos.
- Task 4: Please indicate to which category the photos belong.
- Task 5: Please document your findings of the CCS. You do not think it is necessary to assign the case to another healthcare provider.

As can be seen in Figure 48, some difficulty was observed with tasks 2 and 3. Since the C-Spec is still being developed, a basic prototype of the device was provided to the subjects. Participants struggled with envisioning how this product should be used together with the app and this partly explains the perceived difficulty. For task 3, the nurses also seemed to need more instructions about how the pictures should be made. The most difficulty for all three participants was observed with task 5. It wasn't immediately obvious that the second view within the 'Result' section presents the outcome given by AI. People actually assumed it was their own findings that were presented again. Since the title 'Second Opinion given by AI' was occasionally misread or overlooked, it would be beneficial to rename this.

The questions deployed for the custom Likert scales were the testable targets stated in chapter 5.1.2. To translate this scale with 5 response categories to a scale ranging from 0 to 100, a process of prorating was employed. Each Likert response category was assigned a numerical value, with 0 as the lowest and 100 as the highest value. The intermediate response options were assigned proportionate values between 0 and 100, ensuring an equal distance between each consecutive pair (see Table 1). The resulting variable "Response (0-100)" represents the prorated value of each participant's chosen Likert response for each question. The translation of the Likert scale to a 0-100 scale enabled a more accurate quantification of the testable targets.

The redesign was generally well-received with an average score of 82.8 and a standard deviation of 20.5, suggesting some variability in responses.

Trust in AI

As can be seen in Figure 49, testable target 4a and 4b display remarkable differences. Although participants stated they could not trust the result given by AI to determine the diagnosis and management plan (testable target 4a), they did make use of both the outcome provided by AI and their own knowledge and experience to come to a diagnosis and management plan (testable target 4b).

Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
0	25	50	75	100

Table 1: Conversion table of the Likert scale with 5 categories to a range from 0 to a 100

Participants explained they could not 100% rely on AI to provide the final diagnosis. This result aligns precisely with how the AI was intended to be used, as a second opinion. Two nurses stated that after they could visually observe how AI operated, by seeing the delineation of the detected acetowhite lesion, they trusted the result. In addition, one nurse expressed that mapping out the lesion assists in determining the type of treatment to be given.

Ability to Communicate Effectively

There was also some variability in testable target 5, which has the lowest median at 25.0 (see Figure 49). This indicates a significant need for improvement. The participants clarified they had a generally positive experience with other digital colposcopes. Due to the nurses' history of handling these devices, which make use of similar terminology, the nurses found the interface easy to use. However, they would expect for others healthcare personnel who have not worked with digital colposcopes before or have not been doing typical CCS, to find the redesigned app a little challenging. Hence, these individuals would benefit from more explanation about the terminology.

Conducting the CCS Independently

Although one subject had responded "Neutral" to whether they could conduct the CCS independently (see testable target 7), the other two nurses felt like they would not require assistance in order to use the app.

The responses to the open-ended questions revealed that participant 1 and 2 felt like the app allowed them to devote more attention to patients and to express empathy (design criteria 3). One nurse mentioned the app requests more data about the patient than the IRIS, allowing her to help or treat

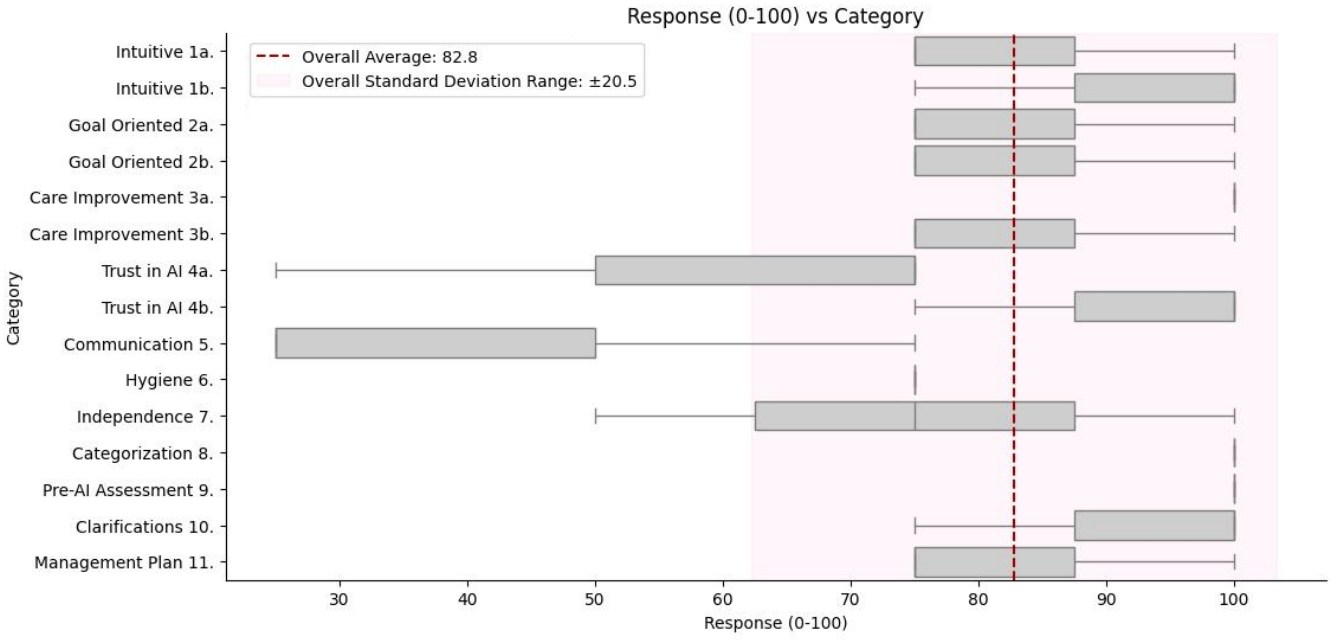


Figure 49: Boxplot analysis per testable target

patients in other ways the client had not sought help for. Although participant 3 answered “no” to this question, this individual did agree the app provides more time to engage with clients.

The subjects unanimously agreed that the app helps healthcare providers to keep track of patient data more efficiently (design criteria 4). Since all necessary information would be inside the app, two nurses declared the paper forms they are using now would be redundant. Furthermore, one nurse mentioned the redesign would be particularly useful to retrieve data when a client misplaces the consultation book.

“Just by having the client's medical records saved on the app, we can just click on the client's name and everything concerning the client will appear, and we are able to source that out without any stress.”

Two out of three nurses expressed interest in purchasing the redesigned application and would favour it over the IRIS, which they are using now. The two nurses noticed new options and features in the application, which are not in the IRIS, and stated the app would reduce manual work and the waiting time of clients. On top of that, both nurses are positive about the integration of AI and expect it will make their work easier by the offering of a second judgement. One nurse stated:
“Maybe you were thinking of something, but AI gives you this, it makes you think more, and then you give a better management to the clients.”

Participant three recognises the potential of the app, but cannot afford to buy it now. This person acknowledged it will take time to develop the AI to ensure it functions effectively and clarified:
“If we will see that this app is better off than the Iris, we'll buy this one.”

5.3.3 Limitations

In order to analyse the user tests, three analytical methods were applied. It is, however, important to point out that the redesign was tested with three participants, all from the less trained healthcare providers’ user group, and only user scenario 1 was evaluated.

Another limitation is that the level of difficulty experienced per task was observed by one moderator, which have made the observations quite subjective. Perhaps that part of the analysis would have been more objective if two or three individuals were present to observe.

6. CONCLUSION

For the further development of the application, a number of short-term improvements and long-term recommendations are proposed. Lastly, a general conclusion was made to answer whether the redesign actually meets the design goal established at the beginning of the design process.

6.1 Recommendations

The recommendations made in this chapter are divided between suggestions for the long- and short-term, and should be implemented to enhance the user interface.

6.1.1 Suggested Short-term Improvements

1. **Providing Specific Instructions**
   While conducting the user tests and executing task 3 to make photos, the nurses needed more directions about how images should be made. Providing specific information on what to do at certain moments would smoothen the image capturing process. An example of an instruction could be: 'Take a single picture of the effect of the VIA test on the cervix by pressing button 'X' on the C-Spec.'

2. **Easing Identification**
   The question mark button next to 'Management Plan' could be used to display example pictures. For instance, by showing photos of an image of a normal cervix, an inflamed cervix, cervix with cervical cancer, etc. Comparing these photos to the ones made on site may help in identifying cervical cancer.

3. **Clearly Presenting AI's Outcome**
   Since user testing participants did not immediately comprehend that the 'Results 2.2.' view (see Figure **X***: Visual depiction of the redesigned digital flow*) is meant to demonstrate AI's findings, it could be better to present this outcome underneath the medical worker's own findings with another title. In stead of calling the header 'Second Opinion given by AI', it would be sensible to change it to something like 'Automatically Generated Result'.

4. **Extra Option for Indicating HPV DNA-Test Result**
   HPV infection with types 16 and/or 18 may indicate that the individual is at a high risk of developing cervical cancer. It would therefore be an asset to have an additional option to select type 16, 18 or other, when an HPV DNA result comes in.

4. **Pre-registering Patients**
   Another feature that came to mind after speaking with Dr. Conrad, is to allow clinicians to fill in the date when a screening will take place on the 'Images 1' view. This would be especially favourable for health campaigns during the planning/organising phase to pre-register patients.

6.1.2 Long-term Recommendations

1. **Viability of Other Redesigned Views**
   Because of time constraints, it was not possible to evaluate the designed views for follow-up with user scenario 2 (see Figure 47). More testing is therefore required to discover whether that part of the design would be viable as well.

2. **Need for an Additional Scenario**
   From conversations with Dr. Conrad it became clear that an additional scenario has to be made for when a patient comes back for another screening (e.g. after 3 years). For this scenario, the 'Patient Registration' view would already be filled in and the medical worker would simply begin with stating the type of screening that will be performed.

3. **Market Introduction**
   Once the application has been properly developed and tested, it would be best to start implementing the digital product in CBC hospitals before deploying it to rural areas. Whether health centers will actually start implementing CCS on a daily basis in the long run, is still unknown.
   The C-Spec and redesigned application should be introduced by a superior or higher ranking doctor to healthcare personnel. This way, medical staff will have a good understanding of how the products should be used (together) and will be more likely to actually adopt the products.

4. **Potential for a Holistic Approach**
   As discussed in chapter 3.2.4, it would be wise to start with the implementation of EMRs. However, to enable the app to work holistically and be usable not only for CCS, but for Women's Health in general, EHRs might be interesting for the long term. Further expansion to other departments in hospitals would then be a possibility as well.

6.2
General Conclusion

The assignment of this master thesis was to redesign the existing GICMED application to enhance the interaction between patient and healthcare provider, and assist in keeping track of patient data more efficiently. While being challenged by GIC Space to design for two user groups, both highly trained medical professionals and less trained healthcare providers, a MVP was created to assess the redesigned application with potential users.

Currently, health campaigns play a significant role in ensuring women are screened on cervical cancer. Although it would be ideal if regular healthcare services were comprehensive and reached all women in the country effectively, for now, supplementary campaigns are still needed. Therefore, a single-user focus for the application remains crucial.

With the redesign, patients who need to be reminded about follow-up or need to be stimulated to undergo treatment are notified. By combining paper work and implementing EMRs, patient data can be stored and accessed digitally, easing and speeding up the CCS procedure. This way, the app allows personnel to work in a efficient manner and devote more time to providing care to patients. Furthermore, EMRs enable exchange of patient data between healthcare facilities, which is particularly beneficial for reducing loss of follow-up if a patient goes to another clinic.

To prevent smartphone contamination, all interactions should occur on the C-Spec itself and not on the smartphone during the procedure. It is therefore recommended to locate all buttons and controls on the device to control it manually, and only use the application during the screening to check and judge the quality of the photos.

The result given by AI should either be conclusive or inconclusive, and there are three possible diagnoses for conclusive cases: ‘negative’, ‘positive’ or ‘suspected cervical cancer’. In order to establish an accurate diagnosis and management plan, AI should solely serve as a second opinion and still rely on the user's own judgement. Moreover, to avoid AI’s diagnosis from simply being adopted, users should be requested to share their findings and diagnosis first, before AI hands over its conclusion.

To evaluate its capabilities, the MVP was deployed at a CBC facility in Cameroon and was assessed by means of user testing. The redesigned application was generally well-received with an average score of 82.8, and participants unanimously agreed that the app helps healthcare providers to keep track of patient data more efficiently. Two out of three subjects agreed the app allows both user groups to devote more attention to patients and to express empathy, and confirmed it would reduce manual work and the waiting time of clients. On top of that, the nurses were positive about the integration of AI and stated they would first give their own judgment and then utilise AI’s findings to come to a final conclusion.

The most important recommendations are to provide precise instructions for capturing photos and to introduce both the C-Spec and app by a superior or higher ranking doctor to healthcare personnel. This way, all medical workers, regardless of their prior experience with digital colposcopes, will know how the products should be used and will be more inclined to actually adopt them. Further testing is, however, needed to discover whether the redesigned views for user scenario 2 would be viable as well.

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APPENDIX

A.
Consent Form Template

TEMPLATE 1: Participant Information/Opening Statement

Key points to include	Suggested text
1. Level (eg: Masters, PhD, research) purpose, potential outcomes and implications of the study 2. The role of TU Delft and any third parties including funding body 3. Who participants are (eg: children, experts, students in a dependent role to the researcher) 4. What exactly what they are being asked to do 5. What if any Personal Data (Personally Identifiable Information and/or Personally Identifiable Research Data) will be collected, and how it will be used, published and managed. This should include clarity on: ○ how the data you collect will be used during the research ○ safeguarding personal information, maintaining confidentiality ○ de-identifying (pseudo/anonymising) data ○ controlling access to data, data archiving and reuse ○ (possible) data publication and dissemination, and ○ data archiving and the retention period for research data or criteria used to determine that 6. What physical, emotional or reputational risks might arise from participation either during or after the study, and what steps will be used to mitigate these risks 7. Participants' right to refuse to answer/withdraw from the study at any time 8. The right (or otherwise) of participants to request access to and rectify or erase personal data 9. Any remuneration for time/compensation for travel 10. Contact details of the Responsible Researcher and procedure for making complaints. **Note: the TUD Human Research Ethics Committee should not be included as a contact and does not deal with participant complaints.**	You are being invited to participate in a research study titled "Using Digital Product Design to support Medical Staff during Cervical Cancer Screenings in Low Resource Settings". This study is being done by Master student Nicole Marques Morgado from the TU Delft in collaboration with GIC Space (startup from Cameroon), TU Delft Global Initiative (fund) and FAST (fund). The purpose of this research study is gathering information from healthcare providers about the procedure of cervical cancer screenings in Cameroon and finding out what the digital need is in order to perform screenings, and will take you approximately 30 minutes to complete. The data will be used to support analysis and to illustrate research findings in publications and presentations about the project. We will be asking you to respond to interview questions about cervical cancer screenings in Cameroon or conduct tasks (such as filling in the onion model). As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by processing and analysing Personal Data anonymously (without your name or other identifiable information). The data will only be accessible to the research team and their TU Delft supervisors. Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. Participants can request rectification or deletion of personal data up to one month after the survey has been conducted. Contact person: Nicole Marques Morgado

TEMPLATE 2: Explicit Consent points

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: [*see points below*]	☐	☐
• *For interviews, observations and conducting tasks, information is written down (no audio or video recording will be made).* • *Data will be collected during the research, such as notes and photos. I give permission for collecting this data and for making photos in which I am not recognisable in publications and presentations about the project.*		
4. I understand that the study will end after approximately 30 minutes.		
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study may involve mental discomfort. I understand that this risk will be mitigated by the possibility to stop the study at any moment.	☐	☐
6. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) [name participant] and associated personally identifiable research data (PIRD) [name hospital, job position] with the potential risk of my identity being revealed.	☐	☐
7. I understand that some of this PIRD is considered as sensitive data within GDPR legislation, specifically [*see points below*]:	☐	☐
• *Religion* • *Political views*		
8. I understand that the following mitigating measures will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach [*see points below*]:	☐	☐
• *Data aggregation* • *Data will only be accessible to the research team and their TU Delft supervisors.*		
9. I understand that personal information collected about me that can identify me, such as my name, name of my hospital or job position, will not be shared beyond the study team.	☐	☐
10. I understand that the (identifiable) personal data I provide will be destroyed one year after completion of this research.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
11. I understand that after the research study the de-identified information I provide will be used for [*see points below*]:	☐	☐
• *Digital product development* • *Illustrating research findings in Nicole's thesis, publications and presentations about the project. Only unrecognisable photos or quotes that cannot be traced back to anyone will be published.*		

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
12. I agree that my responses, views or other input can be quoted anonymously in research outputs.	☒	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
13. I give permission for the de-identified type of hospital and job position that I provide to be archived in education repository so it can be used for future research and learning.	☐	☐
14. I understand that access to this repository is open for everyone.	☐	☐

Signatures

_____ _____ _____

Name of participant [printed] Signature Date

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

_____ _____ _____

Name of witness [printed] Signature Date

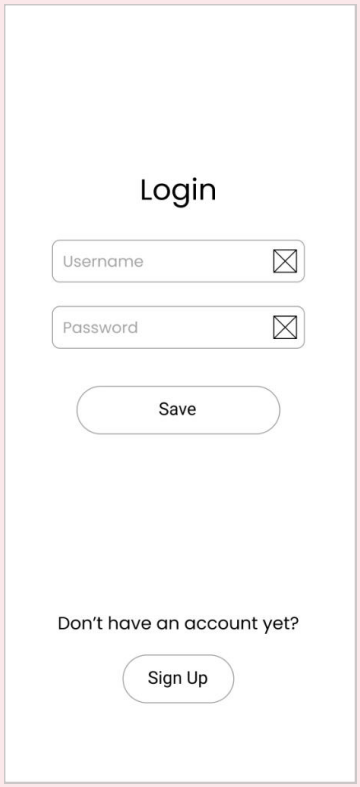
I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

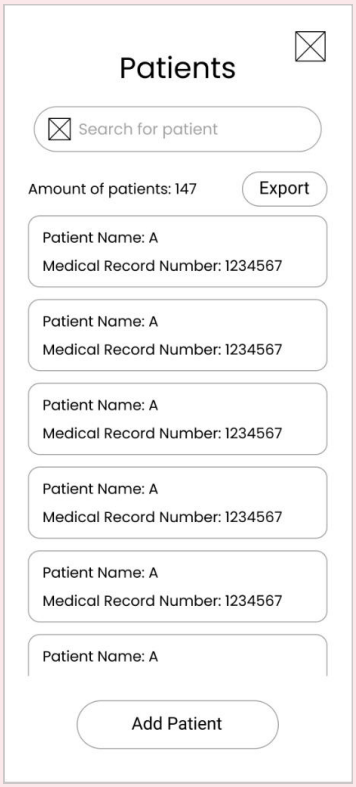
_____ _____ _____

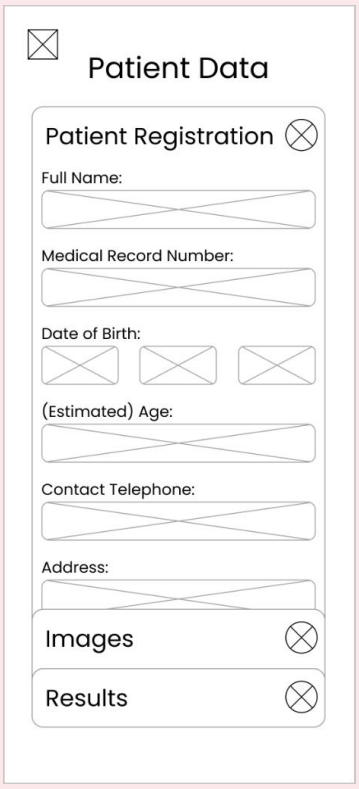
Researcher name [printed] Signature Date

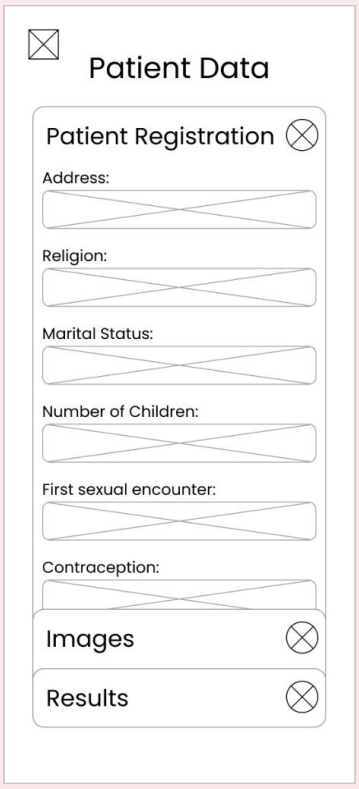
Study contact details for further information: J.C. (Jan-Carel) Diehl, J.C.Diehl@tudelft.nl

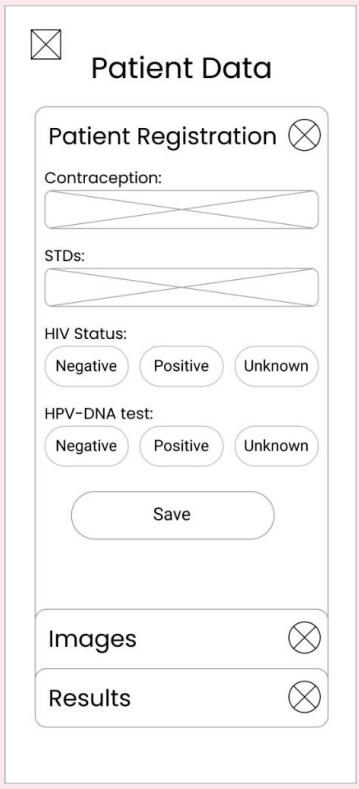
B.
Iteration 1: First Wireframes

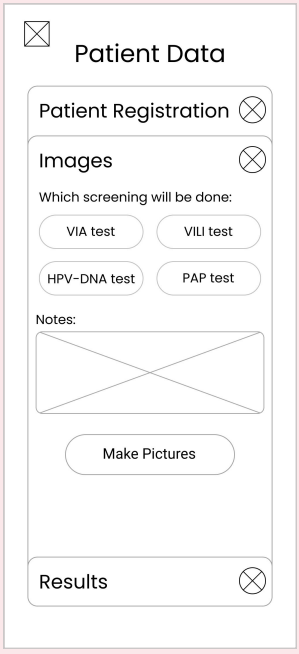


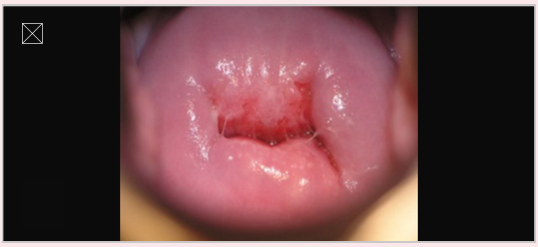


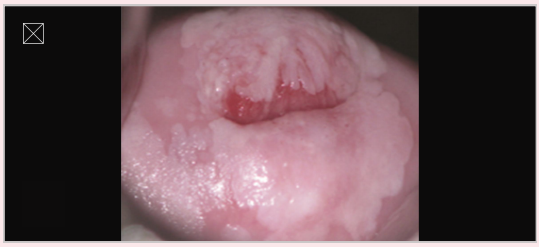


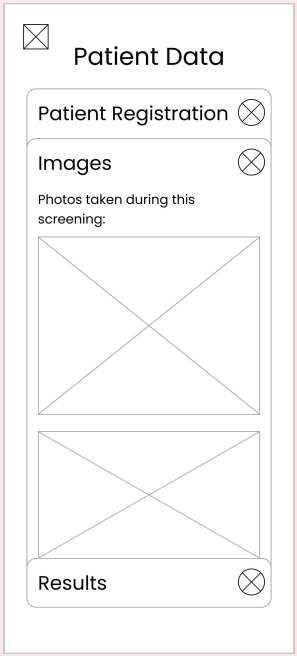


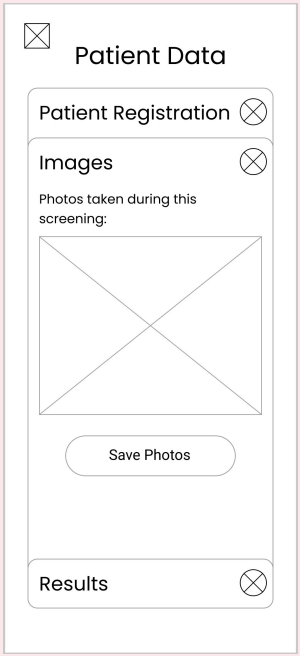


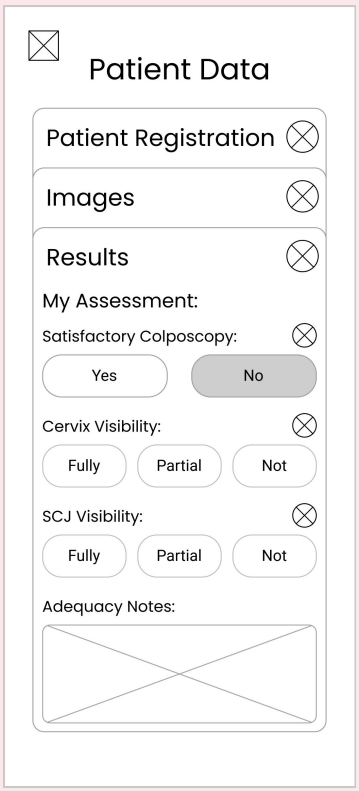

Patient Data
Patient Registration
Images
Which screening will be done:
VIA test
VILI test
HPV-DNA test
PAP test
Notes:
Make Pictures
Results

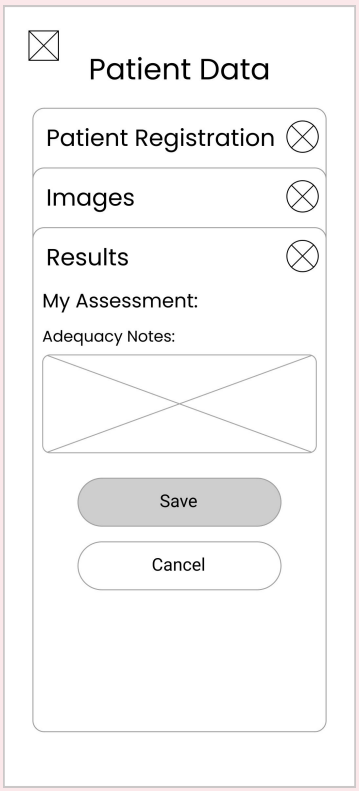


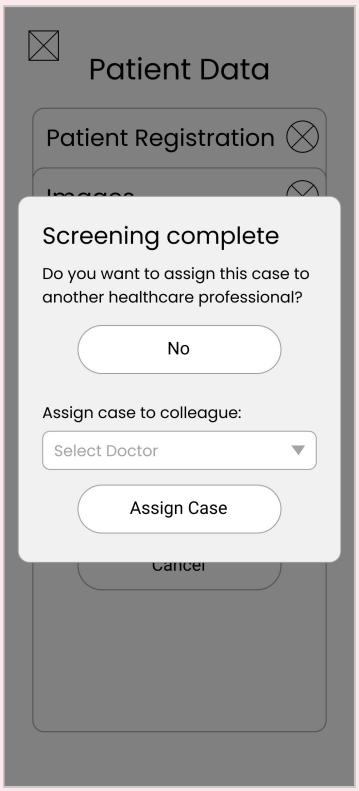


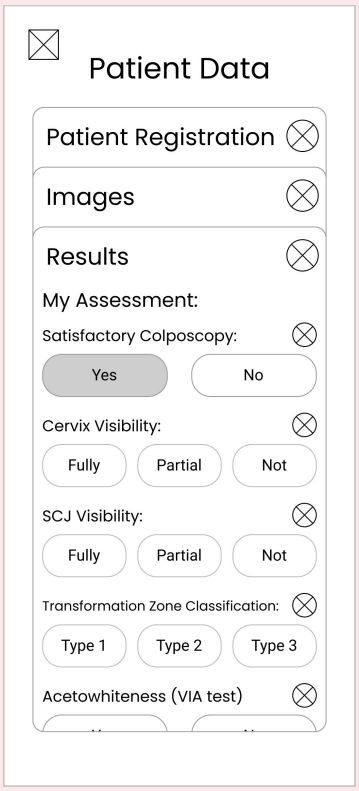

Patient Data
Patient Registration
Images
Photos taken during this screening:
Results

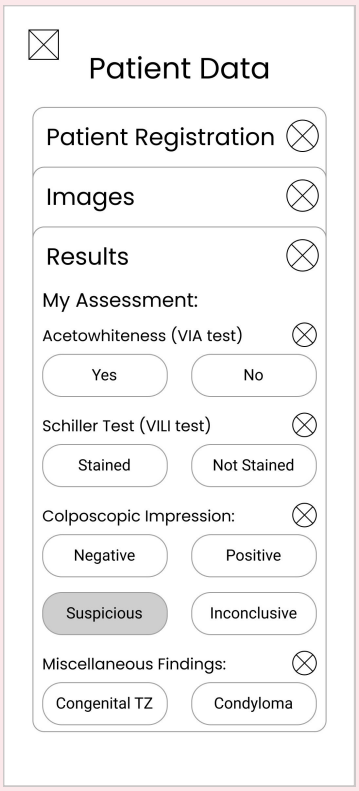

Patient Data
Patient Registration
Images
Photos taken during this screening:
Save Photos
Results

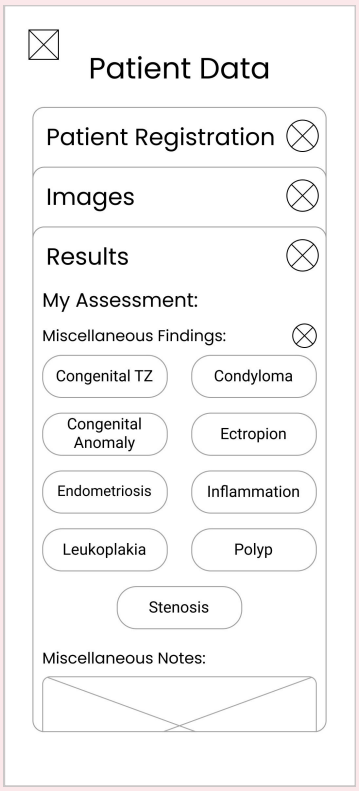

Patient Data
Patient Registration
Images
Results
My Assessment:
Satisfactory Colposcopy:
Yes
No
Cervix Visibility:
Fully
Partial
Not
SCJ Visibility:
Fully
Partial
Not
Adequacy Notes:

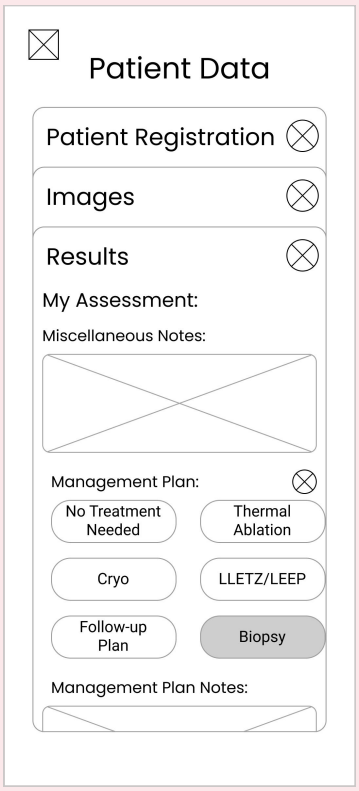

Patient Data
Patient Registration
Images
Results
My Assessment:
Adequacy Notes:
Save
Cancel

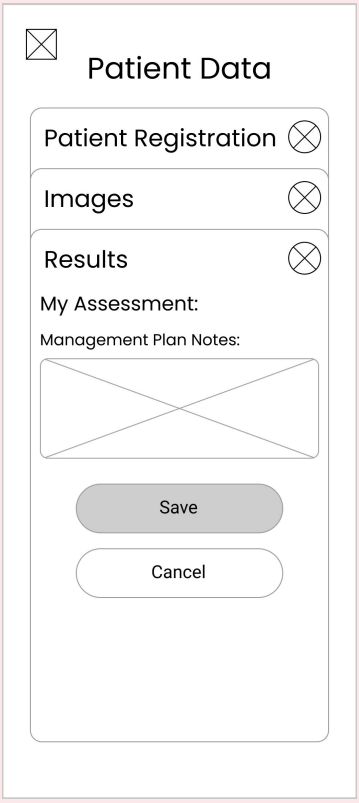

Patient Data
Patient Registration
Screening complete
Do you want to assign this case to another healthcare professional?
No
Assign case to colleague:
Select Doctor
Assign Case

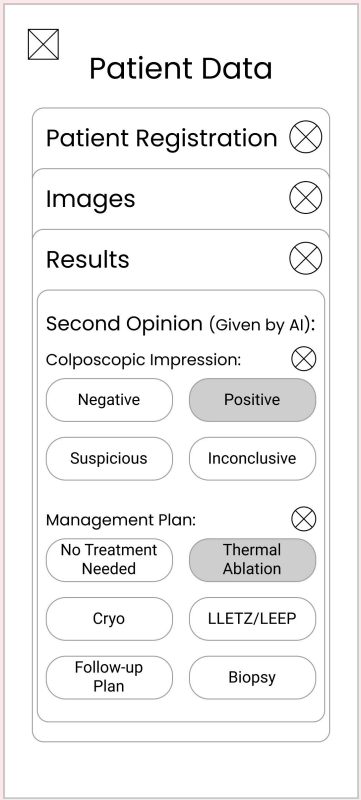

Patient Data
Patient Registration
Images
Results
My Assessment:
Satisfactory Colposcopy:
Yes
No
Cervix Visibility:
Fully
Partial
Not
SCJ Visibility:
Fully
Partial
Not
Transformation Zone Classification:
Type 1
Type 2
Type 3
Acetowhiteness (VIA test)

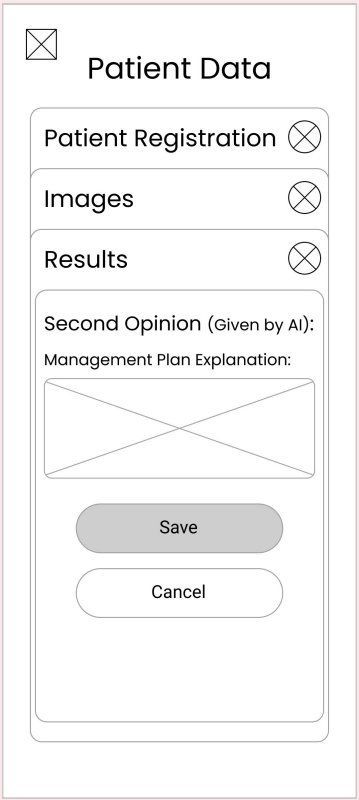

Patient Data
Patient Registration
Images
Results
My Assessment:
Acetowhiteness (VIA test)
Yes
No
Schiller Test (VILI test)
Stained
Not Stained
Colposcopic Impression:
Negative
Positive
Suspicious
Inconclusive
Miscellaneous Findings:
Congenital TZ
Condyloma

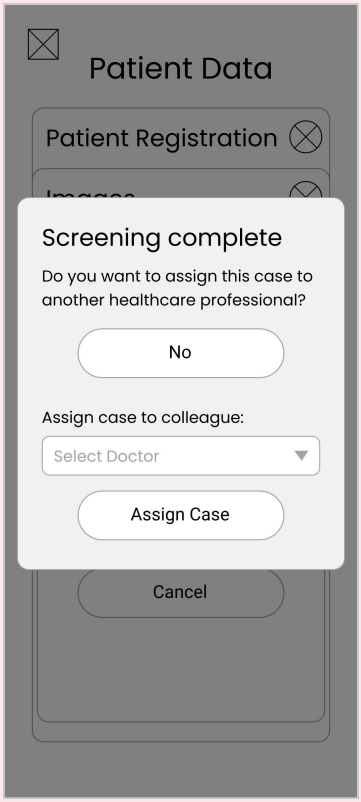

Patient Data
Patient Registration
Images
Results
My Assessment:
Miscellaneous Findings:
Congenital TZ
Condyloma
Congenital Anomaly
Ectropion
Endometriosis
Inflammation
Leukoplakia
Polyp
Stenosis
Miscellaneous Notes:

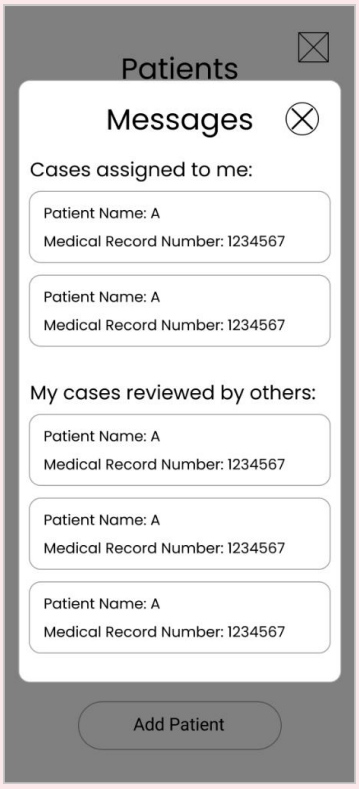

Patient Data
Patient Registration
Images
Results
My Assessment:
Miscellaneous Notes:
Management Plan:
No Treatment Needed
Thermal Ablation
Cryo
LLETZ/LEEP
Follow-up Plan
Biopsy
Management Plan Notes:

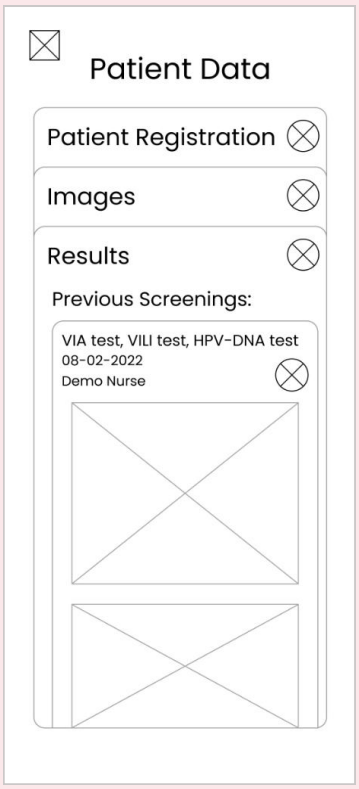

Patient Data
Patient Registration
Images
Results
My Assessment:
Management Plan Notes:
Save
Cancel

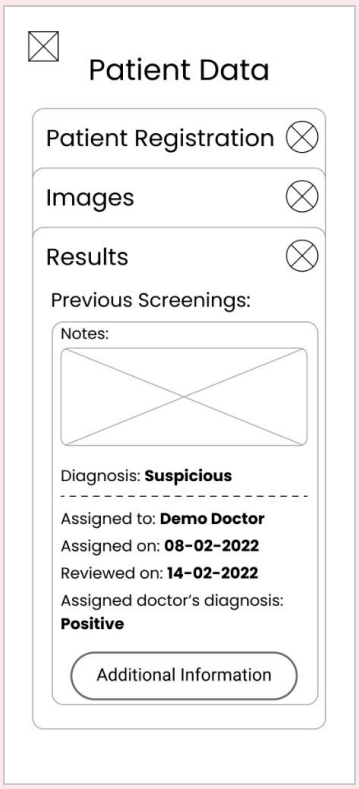

Patient Data
Patient Registration
Images
Results
Second Opinion (Given by AI):
Colposcopic Impression:
Negative
Positive
Suspicious
Inconclusive
Management Plan:
No Treatment Needed
Thermal Ablation
Cryo
LLETZ/LEEP
Follow-up Plan
Biopsy

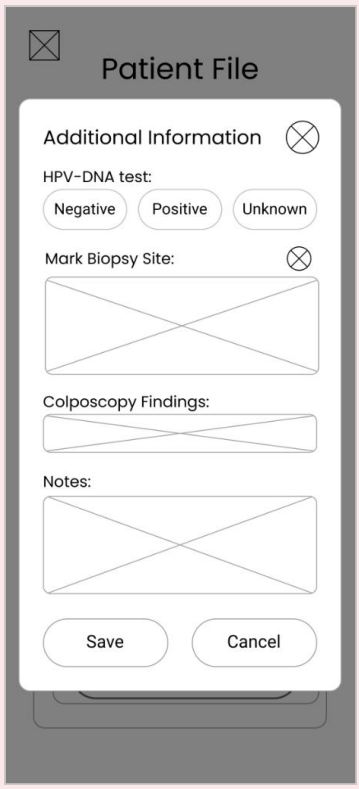

Patient Data
Patient Registration
Images
Results
Second Opinion (Given by AI):
Management Plan Explanation:
Save
Cancel


Patient Data
Patient Registration
Screening complete
Do you want to assign this case to another healthcare professional?
No
Assign case to colleague:
Select Doctor
Assign Case
Cancel

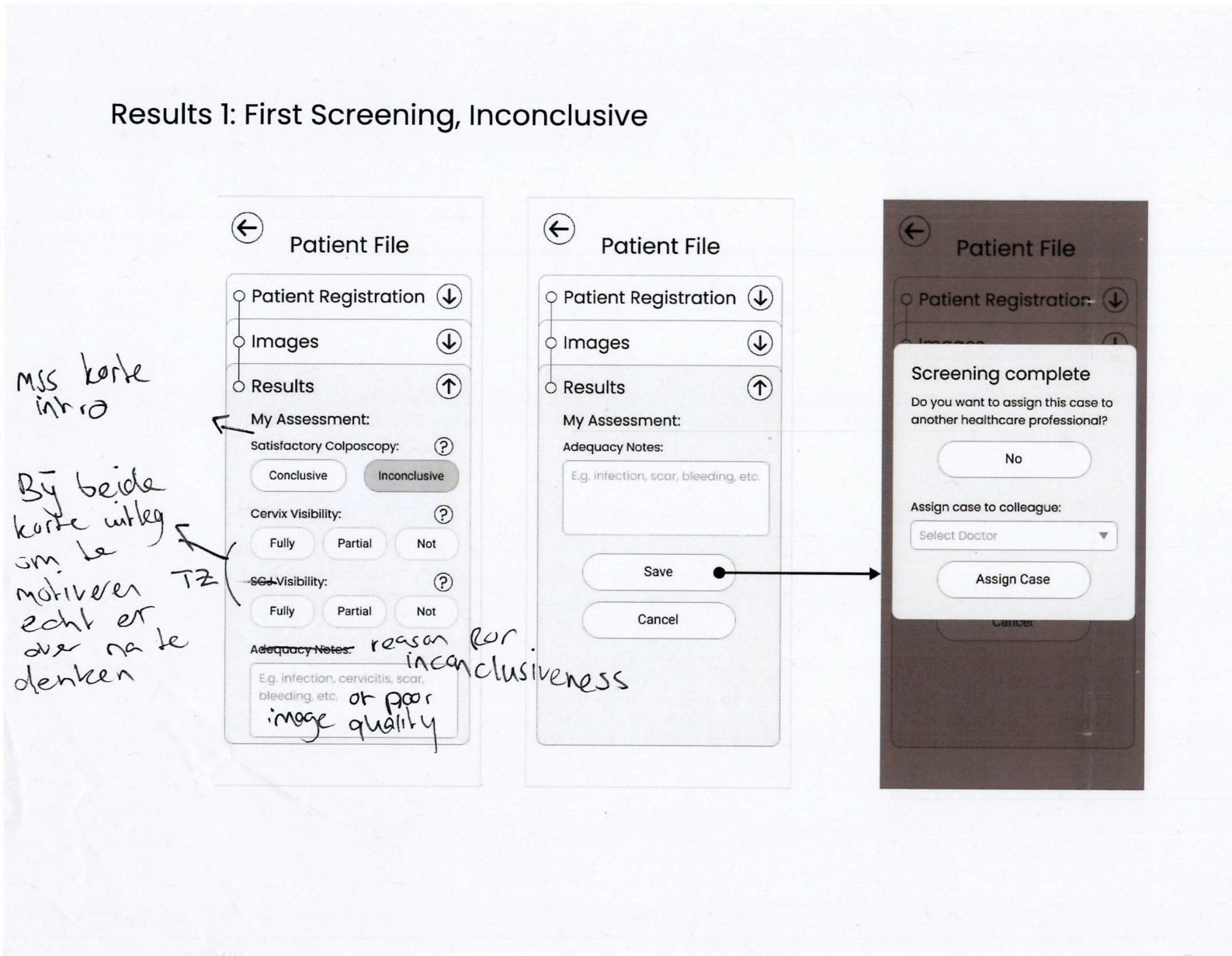

Patients
Messages
Cases assigned to me:
Patient Name: A
Medical Record Number: 1234567
Patient Name: A
Medical Record Number: 1234567
My cases reviewed by others:
Patient Name: A
Medical Record Number: 1234567
Patient Name: A
Medical Record Number: 1234567
Patient Name: A
Medical Record Number: 1234567
Add Patient


Patient Data
Patient Registration
Images
Results
Previous Screenings:
VIA test, VILI test, HPV-DNA test
08-02-2022
Demo Nurse

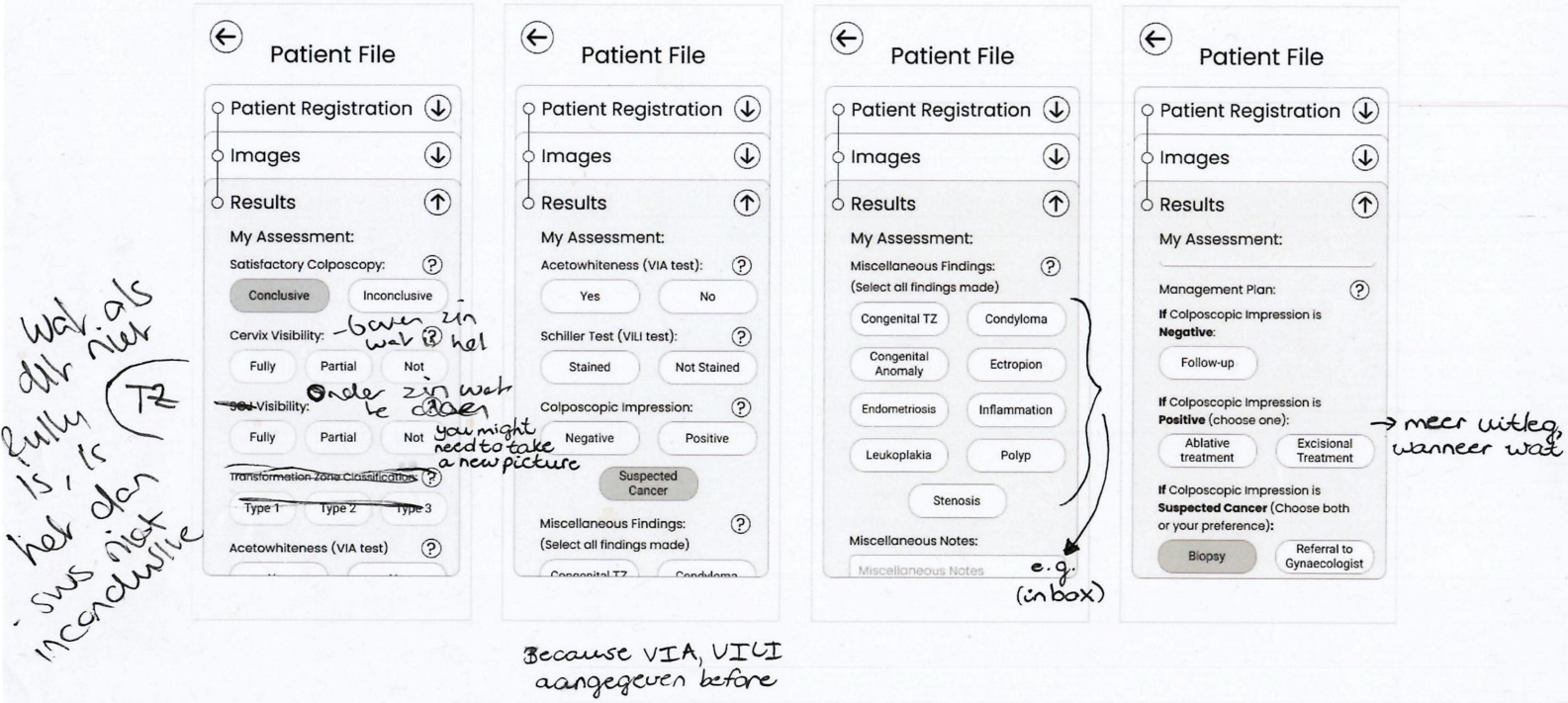

Patient Data
Patient Registration
Images
Results
Previous Screenings:
Notes:
Diagnosis: Suspicious
Assigned to: Demo Doctor
Assigned on: 08-02-2022
Reviewed on: 14-02-2022
Assigned doctor's diagnosis:
Positive
Additional Information


Patient File
Additional Information
HPV-DNA test:
Negative
Positive
Unknown
Mark Biopsy Site:
Colposcopy Findings:
Notes:
Save
Cancel

C.
Evaluation of Final Wireframes with Marijke

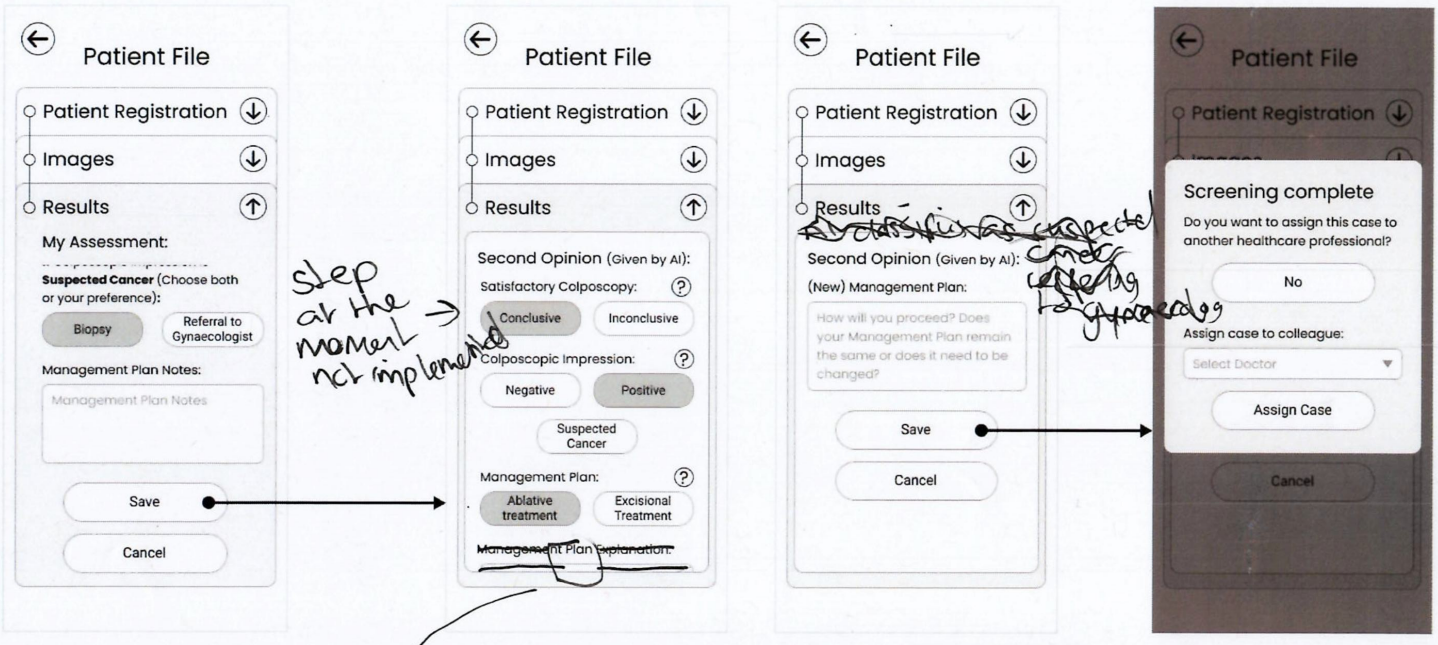


Results 1: First Screening, Conclusive Part 1

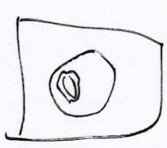


Because VIA, VILI aangegeven before

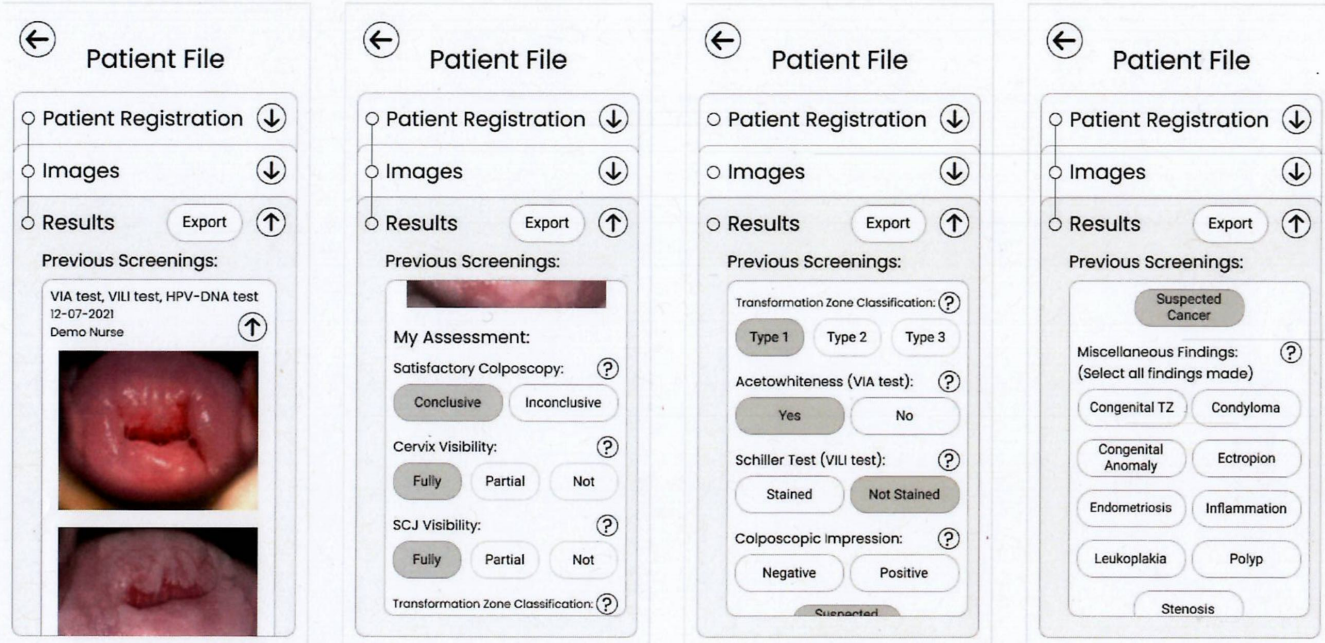
Results 1: First Screening, Conclusive Part 2



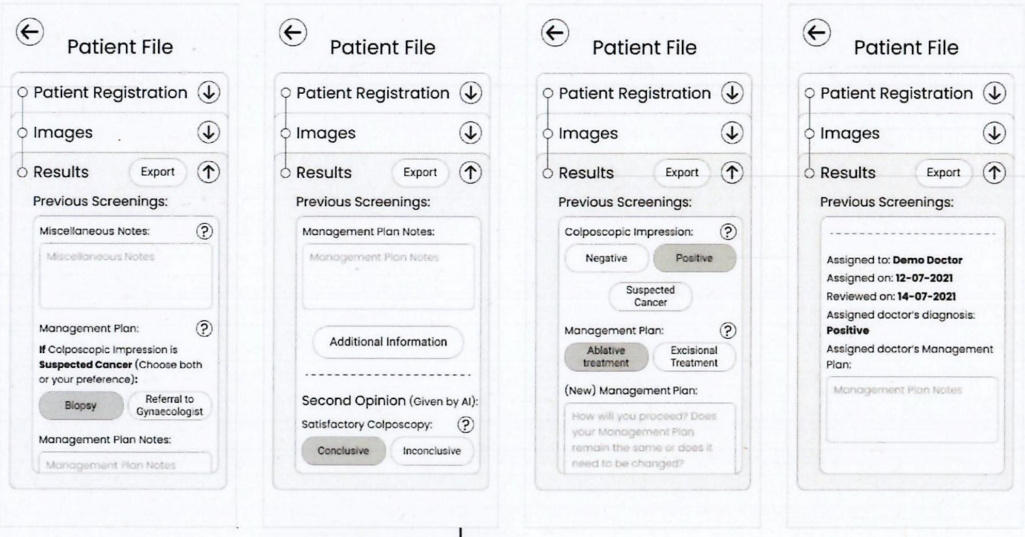
1 out of 4 Possible views after running AI



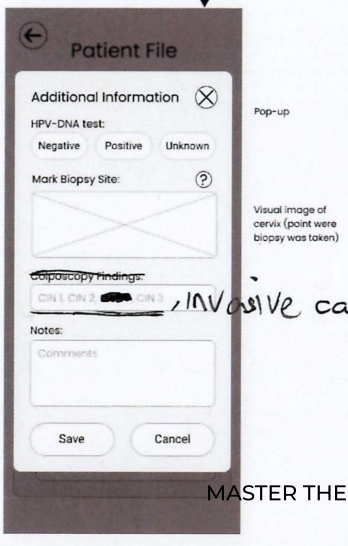
Results 2: Follow-up Part 1



Vanaf 64 check richtlijnen voor follow-up.



Results 2: Follow-up Part 2



Pop-up

Visual image of cervix (point were biopsy was taken)

Biopsy result

, invasive cancer

pap smear result ask Conrad

D.
Filled in User Test Template

User Test 1

Introduction (<5 min)

Welcome
- First of all, thank you for participating in this user test.
- Today we will test an interactive prototype, which is a redesign of the GICMED application that is being developed by GIC Space.
- The aim of the user tests is to gain insights into how potential users experience and interact with the prototype.

Voice and video recording
- The interview will not be recorded. I will be taking notes during the test.

Procedure test
- It will take about 35 minutes to complete the whole test.
- The structure of the user test:
    - First, I will provide some instructions and information for this test.
    - Next, I have some tasks for you, which have to be executed with the prototype.
    - After the tasks, I will conduct an interview with you to evaluate the prototype.

The interface is a work in progress
The prototype you will be testing will not be completely functional, so not all functionalities are working at the moment. The main goal is to test how information is displayed and whether you get a clear impression of the application's capabilities.
The device you have in front of you is called the C-Spec and is being developed by GIC Space to serve as an affordable, partly automated colposcope variant. This device will only be used in the tests to simulate how the products will be used together in the future.

Important
- With this user test, I am testing the design of the application and not your skills. All feedback you provide is valuable, both positive and negative.
- You are free to withdraw from this study at any point.

Thinking aloud
To have a better understanding of your thought process while operating the app, I would like to ask you to think aloud. This helps me to follow your reasoning.

Do you have any questions?

User Scenario (± 15 min)

Before we start with the test, I would like to know about your experience with digital colposcopes.

- Have you used digital colposcopes before? If so, which ones?
- What was your experience with those?
  Notes: Used the IRIS before. Positive experience. “Especially for cases when you find a lesion, you are able to use the green colour filter to help you analyse the lesion better.” Seeing abnormal cells and pictures clearer (better image quality than with smartphone).

User Scenario 1: Screening a New Patient

The participant can now click on the Figma link send to them through email, to see and interact with the redesigned app on their own laptop. The login view is the first screen presented to the participant. They can’t click on the screen or do anything just yet.

Explanation for the participant
I would like to go through a scenario with you, which is a situation you can encounter when conducting a cervical cancer screening. Please think aloud during the test and tell me what you will do and what you think. This way, I can follow your actions and understand what you are doing.

Imagine a new patient comes in to get a cervical cancer screening and it is the patient’s first time being screened. The patient takes a seat in the waiting room and waits for you to invite her into the examination room. Once the patient has entered the examination room, the consultation begins.

The participant is now allowed to click on the screen and interact with the application.

Task 1:
Please register the new patient in the mobile application.
This patient is HIV negative and has never done an HPV-DNA test.
Notes: Recognises the login screen. Understands what the homepage is for: “if you need a particular patient file you just go straight there and click to go directly to the patient’s individual medical record, to find what you are looking for”. Pressed the button “Add Patient”, read all text boxes, clicked on the button ‘Negative’ for the HIV status and ‘Unknown’ for the HPV-DNA test.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Task 2:
Please indicate that VIA and VILI will be performed, but do not yet continue with making pictures.
Notes: “We are already done with patient registration, so the second thing is images.” Understands that there has to be indicated which screening will be done.
Choose one: **No difficulty,** Some difficulty, Significant difficulty

The participant is now handed the smartphone holder and C-Spec.

Please attach the smartphone holder to your lower forearm and place the smartphone on it in landscape mode. Imagine the patient is undressing and getting ready to be screened while doing this.

Imagine you have connected the C-Spec to the smartphone and have made the preparations to insert the C-Spec into the patient. The C-Spec will contain a camera to show the cervix while conducting the VIA and VILI tests, and all buttons and controls will be located on the device and controlled manually.

Task 3:
You can now take photos.
The participant is shown the output of the camera and that images are being captured (cervix before screening, after performing the VIA test, after applying a digital green filter, and after performing the VILI test).
Notes: Expected to make photos with the smartphone. Would make photos in the same sequence as how they were presented.
Choose one: No difficulty, **Some difficulty**, Significant difficulty

Task 4:
Please indicate to which category the photos belong.
Notes: Explains seeing the cervical photos that were just made. Understands that “Select an option” means that the photos need to be labelled to the corresponding category. Labels all photos to the right category.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Imagine you have thrown away all disposables while the patient is getting dressed.
The participant can now remove the smartphone holder from their arm.

Imagine that you think the result is suspected cancer.

Task 5:
Please document your findings of the CCS.
You do not think it is necessary to assign the case to another healthcare provider.
Notes: Explains how to fill in the assessment. Understand assessment is conclusive. Clicks on suspected cancer for “Colposcopic Impression”. Understands what “Miscellaneous Findings” are for and that one can type there what was seen on the cervix. Understands that since the colposcopic impression is suspected cancer, one has to click on “Biopsy” and/or “Referral to Gynaecologist” in Management Plan. Would leave “Management Plan Notes” open until after the biopsy results comes in. Explains that it is not difficult to use and straight to the point, since it has similarities with the IRIS, which she has used before.

Thinks it is interesting that this application maps out the boundary of the lesion.
Thought the view with the “Second Opinion (Given by AI)” was meant to perhaps change your opinion after viewing the delineation of the lesion. Did not understand at first that this view provides the results given by AI (moderator had to explain). Would not agree with the opinion given by AI, trusts own opinion more and would still do a biopsy.

Since there were no other abnormal findings and there were no doubts that a biopsy should be done, this person did not feel the need to assign the case to another doctor.
Choose one: No difficulty, Some difficulty, **Significant difficulty**

Thank you, all tasks have been completed.

Post-test Questions (± 15 min)

I will now ask you some questions to evaluate the prototype.
Please indicate your experience of the app while conducting the tasks on a scale from 1 (strongly disagree) to 5 (strongly agree).

Their experience of performing the task:

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1a. The application can be used immediately.				X	
1b. The application is easy to follow.					X
2a. The application guides me to my end goal in a time-efficient manner.				X	
2b. The application guides me to my end goal in a painless manner.				X	
3a. The application eases the process of CCS.					X
3b. The application saves 5-10 minutes for each patient.				X	
4a. I trust the result given by AI to determine the diagnosis and management plan.		X			
4b. I made use of both the result given by AI and my own knowledge and experience to come to a diagnosis and management plan.				X	
5. The design communicates in the same level of knowledge of both less trained healthcare providers and highly trained medical professionals.		X			
6. While performing the screening, I only used the application to check and judge the quality of the pictures.				X	
7. I could conduct the CCS independently.			X		
8. I selected the corresponding category (e.g. cervix before, after VIA test, etc.) for each picture made after the CCS.					X
9. I filled in my findings and formed an assessment before AI presented its outcome.					X
10. Enough clarifications were provided in the results component of the application.					X
11. I established a 'Management Plan' to determine whether biopsy, treatment or follow-up is needed.					X

Open questions:

- Do you feel like the app allows you to devote more attention to patients and express empathy? **YES** / NO
  If yes, why?
  "Yes, as I'm asking the clients questions, I'm filling the answers directly in the app, and this helps me to interact more with the client. And after assessing the client, I'm able to show the client the various cervigrams (the pictures that we're taking of the cervix)."
- Do you feel like the app helps healthcare providers to keep track of patient data more efficiently? **YES** / NO
  If yes, why?
  "Yes, particularly if the client maybe misplaces the hospital book in which we've written. Just by having the client's medical records saved on the app, we can just click on the client's name and everything concerning the client will appear and we are able to source that out without any stress."
- What do you think about the looks of the app?
  "It looks like a healthcare tool and it's here, I think, to reduce the work of the healthcare provider and also to reduce patient's waiting time. I think it's a good app."
- Are there any missing functionalities in the app that you think are essential?
  "I don't think so. If a client comes, I want to search that client's name. If you type on search, the client's name does not appear with the IRIS. Then you need to start scrolling, scrolling, scrolling, and that takes much time. With this app, once you type the patient's name on the search bar, it takes you directly to the patient's information."
- What are the biggest limitations you noticed, which would affect the app's usefulness as a healthcare tool?
  The participant worries that AI will not be good at accurately predicting diagnoses.
- Please, give a general judgement on the app using rating 1 (very poor) to 10 (excellent): **8**
  "It's an app that is here to enable healthcare workers to input and save patient's data, and it also reduces patient's waiting time. Here we do a lot of manual registration and at times where the consultation book is missing when we already enrolled the client, you have to start searching and searching registers and that increases patient's waiting time and also the work for the healthcare provider. I think this app could relieve us much from that."
- Would you buy this app? **YES** / NO
  If yes, what would be the reason to buy it?
  "Yes, I would like to buy this app. I would prefer this app compared to the IRIS, because of the AI, to make my work easier and it helps to map out a lesion that you would maybe miss out with the naked eye. Mapping out the lesion also helps you to know what treatment to give."

This is the end of the user test.
Thank you very much for participating!

User Test 2

Introduction (<5 min)

Welcome

- First of all, thank you for participating in this user test.
- Today we will test an interactive prototype, which is a redesign of the GICMED application that is being developed by GIC Space.
- The aim of the user tests is to gain insights into how potential users experience and interact with the prototype.

Voice and video recording

- The interview will not be recorded. I will be taking notes during the test.

Procedure test

- It will take about 35 minutes to complete the whole test.
- The structure of the user test:
    - First, I will provide some instructions and information for this test.
    - Next, I have some tasks for you, which have to be executed with the prototype.
    - After the tasks, I will conduct an interview with you to evaluate the prototype.

The interface is a work in progress

The prototype you will be testing will not be completely functional, so not all functionalities are working at the moment. The main goal is to test how information is displayed and whether you get a clear impression of the application's capabilities.
The device you have in front of you is called the C-Spec and is being developed by GIC Space to serve as an affordable, partly automated colposcope variant. This device will only be used in the tests to simulate how the products will be used together in the future.

Important

- With this user test, I am testing the design of the application and not your skills. All feedback you provide is valuable, both positive and negative.
- You are free to withdraw from this study at any point.

Thinking aloud

To have a better understanding of your thought process while operating the app, I would like to ask you to think aloud. This helps me to follow your reasoning.

Do you have any questions?

User Scenario (± 15 min)

Before we start with the test, I would like to know about your experience with digital colposcopes.

- Have you used digital colposcopes before? If so, which ones?
  What was your experience with those?
  Notes: Has used the EVAPro and is now using the IRIS. Participant had a generally positive experience with those devices. “The only problem that we had with the EVAPro was that when you put it on, it takes a long time to come on. And when you want to upload pictures, to remove the pictures from the colposcope to the computer, was not really that easy.”

User Scenario 1: Screening a New Patient

The participant can now click on the Figma link send to them through email, to see and interact with the redesigned app on their own laptop. The login view is the first screen presented to the participant. They can’t click on the screen or do anything just yet.

Explanation for the participant
I would like to go through a scenario with you, which is a situation you can encounter when conducting a cervical cancer screening. Please think aloud during the test and tell me what you will do and what you think. This way, I can follow your actions and understand what you are doing.

Imagine a new patient comes in to get a cervical cancer screening and it is the patient’s first time being screened. The patient takes a seat in the waiting room and waits for you to invite her into the examination room. Once the patient has entered the examination room, the consultation begins.

The participant is now allowed to click on the screen and interact with the application.

Task 1:
Please register the new patient in the mobile application.
This patient is HIV negative and has never done an HPV-DNA test.
Notes: “The screen here looks the same like the IRIS. I see the user's name and then this password. Where I am seeing the user's name, I'll put the user's name there, then put the password, then log in. I'll click on login. Okay wow, so when I click on login then I'll go to add patient, since it is a new patient. Yes, so when I add patient, everything is there, the registration name is there, then medical record. We always have a code we give for any new client, so that when you come for follow-up, we will consider you as a follow-up client and will not give a new number. We are not having religion for the IRIS, marital status we never had it, number of children we never had, first sexual encounter we never had, contraceptives and STD’s we don’t have.” Clicks on the button ‘Negative’ for HIV status and ‘Unknown’ for the HPV-DNA test.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Task 2:
Please indicate that VIA and VILI will be performed, but do not yet continue with making pictures.

Notes: “When you click (on the save button), you saved all this information. You fill in these things before the screening, before you take the pictures, right? So, when you fill everything in, you save, you come now to images where you will now start to take images for the client. Okay, a client comes in for a cervical cancer screening. She doesn't know whether it is VIA, VILI, or it is HPV testing. So, after filling all the other forms, then we have to explain to the client that we have two tests that we do, and it is just for cervical cancer screening.
So, you click VIA and VILI. After doing that, I'll click on ‘Make Photos’. Where do I have to indicate it is follow-up, because previous screening was inclusive?”
Choose one: No difficulty, **Some difficulty**, Significant difficulty

The participant is now handed the smartphone holder and C-Spec.
Please attach the smartphone holder to your lower forearm and place the smartphone on it in landscape mode. Imagine the patient is undressing and getting ready to be screened while doing this.

Imagine you have connected the C-Spec to the smartphone and have made the preparations to insert the C-Spec into the patient. The C-Spec will contain a camera to show the cervix while conducting the VIA and VILI tests, and all buttons and controls will be located on the device and controlled manually.

Task 3:
You can now take photos.
The participant is shown the output of the camera and that images are being captured (cervix before screening, after performing the VIA test, after applying a digital green filter, and after performing the VILI test).

Notes: “I will go down to ‘Make Photos’. I see a cervix. The VIA is positive, this is a cervix after applying the acetic acid and it shows that the cervix is positive. Yes, this is VILI, which also shows a positive cervix.”
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Task 4:
Please indicate to which category the photos belong.
Notes: “After seeing the pictures, you have to come and click save. And if the pictures are not clear, you have to come to edit pictures. Or maybe there were so many pictures that you took and you want to delete some. And if all the pictures are okay, then you click ‘Select an option’. And I'm sure that an option here will be showing the results, where you have to fill the results and the other things.”
Participant did not click on ‘Select an option’ initially, but did do so after repeating the task.
Participant executed the task in the way it was designed.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Imagine you have thrown away all disposables while the patient is getting dressed.
The participant can now remove the smartphone holder from their arm.

Imagine that you think the result is suspected cancer.

Task 5:
Please document your findings of the CCS.
You do not think it is necessary to assign the case to another healthcare provider.
Notes: Participant pressed the button ‘Save’.

“All right, the patient's registration, good, patient's images, good, results is where I had to go to. So here I have to say conclusive or inconclusive. Now what I read here was, was the entire cervix visualised? Was I able to see all the SCJ and the margins? If it is yes, then I will take conclusive. Then cervix visibility, I will take fully if all those things are there and I will take partially if I could not see some other parts. So, let me take fully, because that’s what I saw. Then the transformation zone, it was entirely visible, so it was fully, I saw it well. Then acetowhiteness, that is the VIA test. It was positive. Then the Schiller Test, which is VILI, it was stained.”
Participant clicks on suspected cancer for “Colposcopic Impression”. Participant explains what she looked at for the “Miscellaneous Findings”. Explains that since the colposcopic impression is suspected cancer, she would click on “Biopsy” in Management Plan. Proceeds to click on ‘Save’.

Participant thinks the results are presented again. “The title? It just says, second opinion given by all.” Participant did not read AI but ‘all’. After explaining the text should be read as AI and not ‘all’, the subject did understand what the AI was showing. “Yes, it means that when you click save, the machine automatically gives the information concerning the client.” After seeing the delineation of the lesion: “I can change my management plan, where I clicked biopsy at that time, so now I can go and do thermal ablation to this client.” “After that I come down and click ‘Save’.

“Yes, if I was not convinced about my judgement or of the AI, then I would assign the case to a colleague. If I was convinced about it, I would press ‘No’. But if I was not really convinced, I would seek an opinion from another person, I will come and click here to select another doctor.”
Choose one: No difficulty, **Some difficulty**, Significant difficulty

Thank you, all tasks have been completed.

Post-test Questions (± 15 min)

I will now ask you some questions to evaluate the prototype.
Please indicate your experience of the app while conducting the tasks on a scale from 1 (strongly disagree) to 5 (strongly agree).

Their experience of performing the task:

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1a. The application can be used immediately.					X
1b. The application is easy to follow.				X	
2a. The application guides me to my end goal in a time-efficient manner.				X	
2b. The application guides me to my end goal in a painless manner.					X
3a. The application eases the process of CCS.					X
3b. The application saves 5-10 minutes for each patient.				X	
4a. I trust the result given by AI to determine the diagnosis and management plan.				X	
4b. I made use of both the result given by AI and my own knowledge and experience to come to a diagnosis and management plan.					X
5. The design communicates in the same level of knowledge of both less trained healthcare providers and highly trained medical professionals.				X	
6. While performing the screening, I only used the application to check and judge the quality of the pictures.				X	
7. I could conduct the CCS independently.				X	
8. I selected the corresponding category (e.g. cervix before, after VIA test, etc.) for each picture made after the CCS.					X
9. I filled in my findings and formed an assessment before AI presented its outcome.					X
10. Enough clarifications were provided in the results component of the application.					X
11. I established a 'Management Plan' to determine whether biopsy, treatment or follow-up is needed.				X	

Open questions:

- Do you feel like the app allows you to devote more attention to patients and express empathy? **YES** / NO
  If yes, why?
  Notes: “The app gives you more information about the patient and when you have more information about a patient, you can help the patient in other ways that she wasn’t even coming for. In the hospital, we don’t just treat the patient for what she was coming for.”
- Do you feel like the app helps healthcare providers to keep track of patient data more efficiently? **YES** / NO
  If yes, why?
  Notes: “Yes, we would not need the forms again, because all the information is inside the app, so there is no need filling in the forms again.”
- What do you think about the looks of the app?
  Notes: “It looks modern, it looks nice.”
- Are there any missing functionalities in the app that you think are essential?
  Notes: “No, there is nothing for now that I have noticed that is missing.”
- What are the biggest limitations you noticed, which would affect the app’s usefulness as a healthcare tool?
  Notes: “I can’t think of anything now.”
- Please, give a general judgement on the app using rating 1 (very poor) to 10 (excellent): **8,5**
- Would you buy this app? **YES** / NO
  If yes, what would be the reason to buy it?
  Notes: “If this app was here, I would prefer this app over the IRIS. The app looks more like an upgraded version of the IRIS, because there are some features that are in this app that are not in the Iris. It reduces the number of forms you have to fill in, manual work, because everything will be digital. And then you also reduce the waiting time of the clients, and even have more information and more data. So, I prefer this over the IRIS.”
  “I love the AI, because it gives you a double judgement, maybe you were thinking of something, but AI gives you this, it makes you think more, and then you give a better management to the clients.”

This is the end of the user test.
Thank you very much for participating!

User Test 3

Introduction (<5 min)

Welcome

- First of all, thank you for participating in this user test.
- Today we will test an interactive prototype, which is a redesign of the GICMED application that is being developed by GIC Space.
- The aim of the user tests is to gain insights into how potential users experience and interact with the prototype.

Voice and video recording

- The interview will not be recorded. I will be taking notes during the test.

Procedure test

- It will take about 35 minutes to complete the whole test.
- The structure of the user test:
    - First, I will provide some instructions and information for this test.
    - Next, I have some tasks for you, which have to be executed with the prototype.
    - After the tasks, I will conduct an interview with you to evaluate the prototype.

The interface is a work in progress

The prototype you will be testing will not be completely functional, so not all functionalities are working at the moment. The main goal is to test how information is displayed and whether you get a clear impression of the application's capabilities.
The device you have in front of you is called the C-Spec and is being developed by GIC Space to serve as an affordable, partly automated colposcope variant. This device will only be used in the tests to simulate how the products will be used together in the future.

Important

- With this user test, I am testing the design of the application and not your skills. All feedback you provide is valuable, both positive and negative.
- You are free to withdraw from this study at any point.

Thinking aloud

To have a better understanding of your thought process while operating the app, I would like to ask you to think aloud. This helps me to follow your reasoning.

Do you have any questions?

User Scenario (± 15 min)

Before we start with the test, I would like to know about your experience with digital colposcopes.

- Have you used digital colposcopes before? If so, which ones?
- What was your experience with those?
  Notes: Previously used the EVAPro. “It was good, it was actually good but we had challenges in sharing photos from there and at one point it was too slow, it was not loading. One challenge that we noticed was that the software got outdated and we didn't know that we needed to update. So, we had challenges using that for a while and we were unable to use it.”
  Subject is now using the IRIS.

User Scenario 1: Screening a New Patient

The participant can now click on the Figma link send to them through email, to see and interact with the redesigned app on their own laptop. The login view is the first screen presented to the participant. They can’t click on the screen or do anything just yet.

Explanation for the participant
I would like to go through a scenario with you, which is a situation you can encounter when conducting a cervical cancer screening. Please think aloud during the test and tell me what you will do and what you think. This way, I can follow your actions and understand what you are doing.

Imagine a new patient comes in to get a cervical cancer screening and it is the patient’s first time being screened. The patient takes a seat in the waiting room and waits for you to invite her into the examination room. Once the patient has entered the examination room, the consultation begins.

The participant is now allowed to click on the screen and interact with the application.

Task 1:
Please register the new patient in the mobile application.
This patient is HIV negative and has never done an HPV-DNA test.
Notes: “I would put my username and password in the screen here.” Proceeds to click on ‘Login’. Okay, I am seeing that this has already some client history, but I think I need to go to new patient. Clicks on button ‘Add Patient’. Reads all the textboxes. Clicks on the button ‘Negative’ for HIV status and ‘Unknown’ for HPV-DNA test.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Task 2:
Please indicate that VIA and VILI will be performed, but do not yet continue with making pictures.
Notes: Participant clicks on ‘VIA Test’ and ‘VILI Test’, and then on ‘Make Photos’.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

The participant is now handed the smartphone holder and C-Spec.

Please attach the smartphone holder to your lower forearm and place the smartphone on it in landscape mode. Imagine the patient is undressing and getting ready to be screened while doing this.

Imagine you have connected the C-Spec to the smartphone and have made the preparations to insert the C-Spec into the patient. The C-Spec will contain a camera to show the cervix while conducting the VIA and VILI tests, and all buttons and controls will be located on the device and controlled manually.

Task 3:
You can now take photos.
The participant is shown the output of the camera and that images are being captured (cervix before screening, after performing the VIA test, after applying a digital green filter, and after performing the VILI test).
Notes: Participant acts out how the app and the device will be used together. “This is what I would do, with my smartphone on my arm, the camera has to guide me, I have to be working and looking at the smartphone. So now, as I am trying to position it to look at the cervix, I am working with two hands. I am trying to see the cervix and I am also looking at the screen. Once I am balanced, I take a photo with the device.”

Participant initially thought the grey rectangle was a button to snap pictures. Realised it was just to show the output of the camera when the images were shown one by one.
Choose one: No difficulty, **Some difficulty**, Significant difficulty

Task 4:
Please indicate to which category the photos belong.
Notes: “It has a dropdown option right, where I need to let know which image is the cervix before, which one is after VIA, VILI…”
Proceeds to choose the right option for each image and clicks on ‘Save’.
Choose one: **No difficulty**, Some difficulty, Significant difficulty

Imagine you have thrown away all disposables while the patient is getting dressed.
The participant can now remove the smartphone holder from their arm.

Imagine that you think the result is suspected cancer.

Task 5:
Please document your findings of the CCS.
You do not think it is necessary to assign the case to another healthcare provider.
Notes: Starts reading the text and quickly goes though the results, pressing the right buttons. “Now, if I had any miscellaneous findings, maybe I would describe how the lesion was, or if I saw that there was an infection, I can describe it here.” Participant reads further. “Okay, if it is positive it's ablative treatment, but it was suspicious, so I would do a biopsy or I refer.” Pressed the ‘Save’ button.

Participant reads over the heading: ‘Second Opinion (Given by AI)’, asked the moderator to confirm that these results were automatically generated. “This lesion looks like a high-grade lesion, it’s better to do a biopsy or we do excisional treatment, as the lesion already covers more than 75% of the ectocervix. Actually, a biopsy may not really be a good treatment type for this kind of big lesion. AI thinks that this lesion should be treated with ablative treatment. I don't think so. This lesion looks like a high-grade lesion, and with high-grade lesions, you don't treat with ablative treatment.”

Participant clicks on ‘Save’. “Do you want to assign this case to another healthcare? Ah, okay, does it mean that if you assign this to another doctor, the information can be sent to the person or how is it?
Needed more explanation about this feature.
Choose one: No difficulty, **Some difficulty**, Significant difficulty

Thank you, all tasks have been completed.

Post-test Questions (± 15 min)

I will now ask you some questions to evaluate the prototype.
Please indicate your experience of the app while conducting the tasks on a scale from 1 (strongly disagree) to 5 (strongly agree).

Their experience of performing the task:

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1a. The application can be used immediately.				X	
1b. The application is easy to follow.					X
2a. The application guides me to my end goal in a time-efficient manner.					X
2b. The application guides me to my end goal in a painless manner.				X	
3a. The application eases the process of CCS.					X
3b. The application saves 5-10 minutes for each patient.					X
4a. I trust the result given by AI to determine the diagnosis and management plan.				X	
4b. I made use of both the result given by AI and my own knowledge and experience to come to a diagnosis and management plan.					X
5. The design communicates in the same level of knowledge of both less trained healthcare providers and highly trained medical professionals.		X			
6. While performing the screening, I only used the application to check and judge the quality of the pictures.				X	
7. I could conduct the CCS independently.					X
8. I selected the corresponding category (e.g. cervix before, after VIA test, etc.) for each picture made after the CCS.					X
9. I filled in my findings and formed an assessment before AI presented its outcome.					X
10. Enough clarifications were provided in the results component of the application.				X	
11. I established a 'Management Plan' to determine whether biopsy, treatment or follow-up is needed.				X	

Open questions:

- Do you feel like the app allows you to devote more attention to patients and express empathy? YES / **NO**
  If yes, why?
  Notes: “I think to a level. The questions are straight to the point. In a one-on-one conversation with a client, that's where you get to know some things and you can express some empathy, emotions. However, I think it gives you time to engage with, to talk to the client.”
- Do you feel like the app helps healthcare providers to keep track of patient data more efficiently? **YES** / NO
  If yes, why?
  Notes: “Yes, very well, because the paperwork is very cumbersome.”
- What do you think about the looks of the app?
  Notes: “It’s good. I think as times are changing, before now we did not have this, and if this is coming up already, I mean, I think it's a very nice tool that can be used for data, to store a lot of data. I think it's nice. I appreciate it.”
- Are there any missing functionalities in the app that you think are essential?
  Notes: “I think it should be in a way that you can be able to cast it to a smart television. You are casting it so that the client can also be comfortable seeing what you're doing.”
- What are the biggest limitations you noticed, which would affect the app’s usefulness as a healthcare tool?
  Notes: Participant pointed out the same thing as in the previous question: an option to cast the output of the camera to a television in the examination room.
- Please, give a general judgement on the app using rating 1 (very poor) to 10 (excellent): **7**
  “It looks good. I think I can rate it up to seven, because it's a good app. And I know that you are building the AI part of it, we are trying to see how it works now. So, I think it's good, but it's not yet the best, but it's good.”
- Would you buy this app? YES / **NO**
  If yes, what would be the reason to buy it?
  Notes: “Not yet. It looks like the Iris, though it has other functions like the AI part of it, which the Iris doesn't have. For now, we are still piloting the Iris. So, if in the near tomorrow, if we see that this app is better off than the Iris, we could just drop it. So as times are evolving, if we will see that this app is better off than the Iris, we'll buy this one. But for now, we can't afford to buy this one now.
  Everybody is striving to get a better thing. So, in the near future, why should we not go for it? Healthcare is dynamic, it should be moving us. Innovations are coming. You cannot remain in one place.”

This is the end of the user test.
Thank you very much for participating!