# FISHING

## An E-Learning Platform and ERP system for Limited Resource Environments

**Report submitted as part of the Engineering World Health Design Competition**

**by**

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# 1 Motivation

Fishing evolved whilst working in Entebbe Hospital and Kisugu Health Centre. It did not take long before we noticed the absence of and incorrectly informed user guides for medical equipment. User training was rarely given to on the ground healthcare workers and there were no oversight capabilities for the management of equipment (See appendix B). In one hospital a bacterial incubator incorrectly labelled as an autoclave was being used to sterilise dental equipment and in another health centre, a water bath was being used to sterilise medical equipment in the maternal department. Often repairs were made and money spent on spare parts to return the following week and find the same piece of equipment broken or unlocatable. These experiences along with many others highlighted the failures of equipment donation and the difficulty in managing medical equipment without any oversight. Disheartening we found that despite our efforts to repair equipment and take inventories, these only proved to be a short term solution. This encouraged us to find a solution that would address the upstream issues affecting the accessibility of medical equipment.

The developed world has seen how the power of information (in particular via the internet) has forced economic development to accelerate faster than that of the industrial age. Information that is accurate and reliable provides valuable insight and identifies flaws in an existing system. The first phase of Fishing was built to test whether this phenomenon was true regardless of the surrounding economic environment. What is now the first stage of Fishing was originally an offline E-Learning library called Health Care Technology Trainer. After implementing it at Entebbe, and showcasing in a presentation to Engineering World Health (EWH) affiliated hospitals in Uganda, we noticed that the idea was well received in that it was a novel approach to solving a bigger issue.

After finishing the program, we decided to continue development and test whether such an approach could address some of the issues shown in figure 1. Phase One covers the implementation of our original prototype (See Section Implementation of Prototype). Phase two and three discuss how the original idea evolved into what is now Fishing and describes its functions and how they will impact developing health care systems. Currently, Fishing is at Phase two, and we aim to gather evidence of our phase one prototype when applicable.

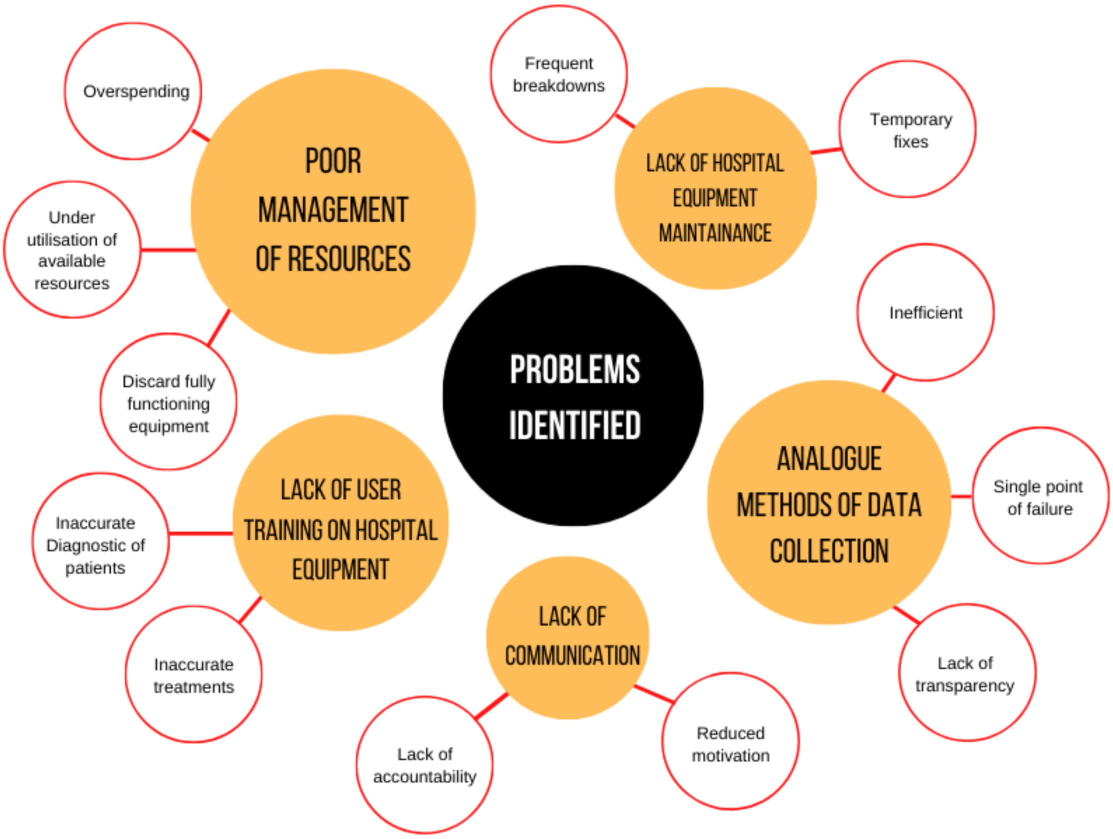



Figure 1: Break down of problems identified

# 2 Problem Definition

An important part of a healthcare system is its medical equipment. Medical equipment operations are required for diagnosis, treatment and rehabilitation procedures carried out in all healthcare facilities [1]. Accessing functioning medical equipment in the developing world is a challenge. It has been estimated that 80% of healthcare equipment in developing countries is funded by international donors or foreign governments [2]. Estimates from the World Health Organisation have shown that 50-80% of the medical equipment in these countries are broken or not functional [2]. This has repercussions for health outcomes where patients suffer from a lack of accurate diagnostic or inadequate treatment [3]. Additionally, it puts a strain on healthcare facilities funds, as they are required to store large amounts of the out of service equipment known as 'equipment graveyards'. Throughout the equipment's life-cycle it will require installation, user training, maintenance and repair. Where the logistics needed to support the entire life-cycle of the donated equipment in the developing world are often neglected [2].

Poor accessibility and usability of medical equipment in developing countries is due to a multi-faceted, systemic failure (See Appendix G - Figure 16) [4]. When equipment is donated there is no local expertise to install, commission, maintain or repair. Often the equipment is accepted by a healthcare facility without appropriate knowledge, or any user-training provided [2]. In the case where a manual is supplied, it is written in technical terminology or foreign language making it difficult to interpret. Often the received equipment is not recognisable and therefore ignored. Whilst in other circumstances it is improperly installed, incorrectly maintained and incorrectly operated; jeopardising the safety of the patient and healthcare workers. The incorrect installation, maintenance and use of medical equipment lead to frequent breakdowns, the lack of infrastructure exacerbates the problem. Furthermore, fluctuations in electricity or lack of distilled water lead to further equipment breakdowns. For the high degree of equipment breakdowns, there is little management, where temporary fixes are repeatedly made with little resources.

Both limited access and high frequency of equipment breakdown is underlined by lack of user training and lack of effective technical support [5]. This is met by the lack of oversight and mismanagement of the medical equipment. The present trend has also been a cause of concern raised by the World Health Organisation (WHO). The WHO encourages donors of medical devices to have a policy in place for training, maintenance and reporting problems with medical equipment [6]. The purpose of this policy is to ensure all donated equipment is assessed to meet international safety standards and are put in place to avoid poor utilisation of equipment in developing countries.

## 2.1 Clinical Solution/Utility

To resolve these systematic issues we created our solution Fishing. Fishing will provide medical equipment training via E-Learning modules which include: learn as you go videos, operation and maintenance guides and quizzes. Enterprise Resource Planning (ERP) tools will also be integrated into the management of equipment inventory and breakdowns. Management of breakdown reporting will help identify inefficiencies, whilst a digitised inventory will create an overview of resources needed to develop and maintain equipment. By educating rather than donating, our vision is to provide a more effective means of maximising existing resources to improve the quality of healthcare provided. *"Give a man a fish and you feed him for a day, teach a man to fish and you feed him for a lifetime"*

# 3 Impact on the Developing World

Africa receives 30% of the worldwide aid, amounting to over US$1 trillion of development-related aid in the past 50 years [4]. Despite this poverty has decreased in all regions of the world except for Africa [7]. In sub-Saharan Africa, 45% of countries substantially failed to achieve the Millennium development goal of extreme poverty target [8]. An observation from the World Health Organisation (WHO) showed that when it comes to healthcare that 20-40% of the aid is wasted [9]. From this health link expenditure, an estimated 10-25% is spent on procurement such equipment and infrastructure is lost to corrupt practices [9]. Multiple pieces of literature have found a weak link between public health expenditure and health outcomes in the developing world [6]–[10]. Collectively these have emphasised the need to promote active measures which are aimed at building productive capacity. Alternative to individual ad hoc assistance or further aid promises, systemic improvement is necessary within the multi-lateral architecture of healthcare facilities within sub-Saharan Africa. For our developing world solution, we have aimed to systematically target the problem of accessibility to medical equipment; providing a tool which allows the local healthcare systems to develop independently and improve the efficiency of healthcare delivery organically.

## 3.1 Impact on Healthcare

Fishing's multi-featured approach addresses user training, breakdown reporting, and management of equipment life-cycle. Fishing will not only implement a standardized training, breakdown reporting and inventory system. But subsequently will allow total oversight of staff training and equipment life-cycle (within and between healthcare facilities), improve reporting of broken equipment, improve the planning of limited resources (including supply chain management) and improve efficiency in workflow. Ultimately Fishing has the opportunity to improve existing methods of treatment and diagnosis. Thus reducing patient trauma.

User training is an important part of modern healthcare service and is often cited as a way to improve the quality of healthcare [11]. Instead of embodying the usual top-down approach, Fishing aims to directly deliver user training to health care workers who operate medical devices daily. This delivery of user training incorporates a socio-technical approach focused on consistently and continually improving the interactions between healthcare staff and medical equipment. With wider-spread equipment knowledge, staff have improved abilities to treat and diagnose patients.

Often the life-cycle of medical equipment is not tracked and up to 70% of medical equipment stands idle [12]. The only verifiable way to determine what equipment is usable is to take inventory [13]. In hospitals where the inventory is recorded, it is usually performed using an analogue 'pen to paper' system. Reporting broken down equipment is often only done once urgently required and past repairs are not logged. These practices are extremely labour intensive. The autonomic and fragmented management of medical equipment life-cycle increase its inefficiencies. This solution provides a digital platform which tracks inventory and allows the equipment failures to be effectively reported. Digitising the method of inventory management will present a new level of efficiency as hospitals will more effectively manage and allocate medical equipment, ensuring does not reach early retirement. Better equipment management will not only increase the amount of equipment being used for treating and diagnosing patients, but will also reduce the device-related incidence and improve patient safety. Where a study on patient safety incidents associated with equipment found that device-related incidents were caused by device failure (43.8%), inappropriate use (29.3%), lack of training (12.3%) and inadequate maintenance (1.5%) [14].

# 4 Performance Requirements

Fishing's key performance requirement is that hospital staff have access to a smartphone. A study we conducted at Entebbe Regional Hospital showed that 97% of staff owned a smartphone (See Appendix B). Smartphones will be the tool through which healthcare workers can view operation and maintenance guides, report equipment failure, and complete e-learning modules. For Fishing to be accessible to all, the app will be majorly offline, with optional online functionality. Whilst internet services are available and have been improving over the last ten years [15], further on the ground pilot research has to be completed before determining whether the opportunity cost of using a completely offline network (such as peer to peer mesh, wireless local area network) is suitable over existing 3G/4G networks. (See Appendix F.1 - Comparison between the 3 network technologies)

For the healthcare worker's app interface the e-learning modules containing operation and maintenance guides will function on a local interface and will not require online functioning. However, to raise a ticket for the failure of equipment or interact with other users through the staff database, online functioning is required. For the BMET's equipment managing app interface, both responding to breakdown tickets and performing inventory will require online functioning. To ensure that any all collected data is backed-up, both the inventory database and staff database will be stored on a cloud database via the internet. The databases will primarily be available to the facilities administrators and then sent remotely to any participating third parties. For a dissection on how these features and databases will interact refer to Appendix H.

Another important requirement for Fishing's success is to establish productive user-engagement. To ensure Fishing mitigates the problem of a lack of user training, and inefficient resource management it is vital that users consciously use Fishing in such a way that complements their designated role. Thus, user engagement will be embedded through the structure of Fishing.

Fishing will need to employ a human-centred design approach to promote co-design and ensure that training material is available in appropriate languages, and designed considering the healthcare workers of specific countries. Designing with local expertise will allow us to communicate documentation to end-users in a more intuitive manner. User manuals that come with donated equipment often contain large amounts of text, with few graphics, which can intimidate users. Videos explained with local engineers could create a more relatable and user-friendly experience (see Appendix B).

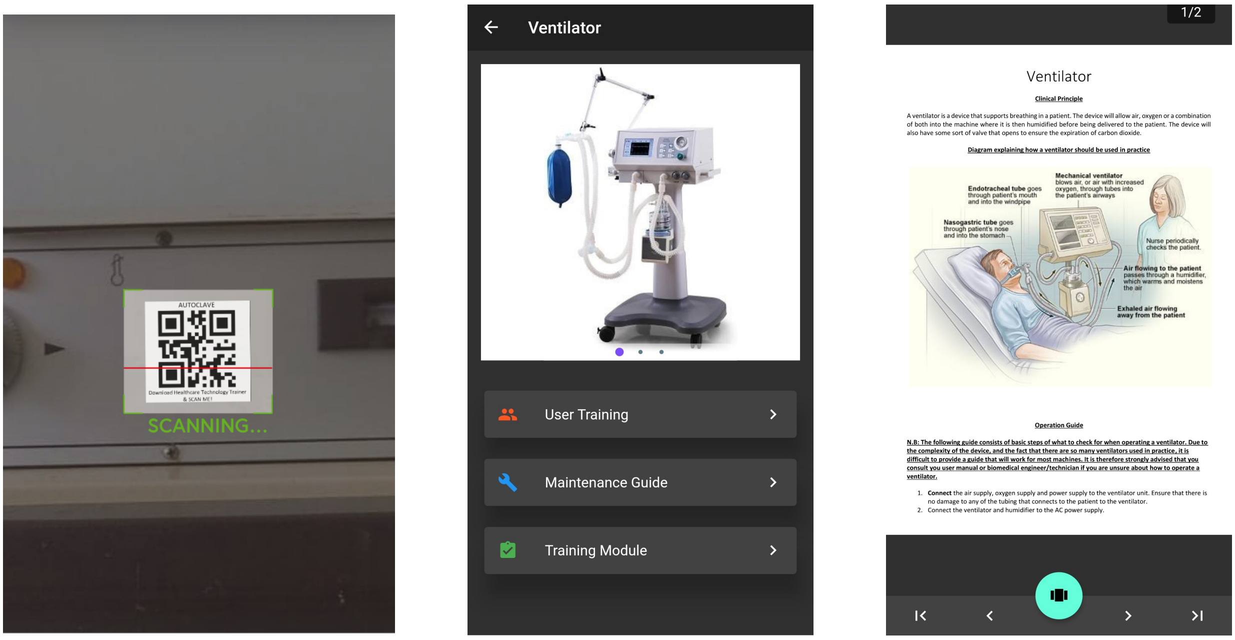
Gamification of Fishing will also prove essential for encouraging user engagement and participation. Gamifying E-Learning will not distract health care workers as it will only introduce points systems and cosmetic elements that motivate them to continue completing modules to gain more points. Mobile applications that gamify their service show to have a better impact on encouraging users to learn when compared to other learning platforms [16]. The ability to create reward systems and social pressure motivates users to move towards a goal and encourages continuous self-improvement via healthy competition. Incorporating these elements into the design process will be vital to ensuring the product performs as more than just supplementary training material.

Finally, for any E-Learning material to improve the quality of a service, it is imperative that the information provided is correct and verified by professionals.

# 5 Implementation of Prototype

## 5.1 Phase One

A time horizon of five weeks in Ugandan Hospitals limited the development of a full-scale prototype. So that we could still examine the feasibility of such a technology in the developing healthcare system, we developed a minimum viable product and installed QR codes around the hospital. This provided a completely offline library of E-Learning modules for healthcare workers (See Appendix A). This offline library was built as an Android Application, using the Flutter framework. The app allowed users to scan QR codes attached to medical equipment. Once scanned, the app prompted the corresponding medical device's module. Each module contained an operation guide, maintenance guide and quiz used to test the user's understanding of the learning material and medical equipment.




(a) Users can scan QR codes which are attached to medical devices

(b) Once scanned the app prompts the corresponding medical device's module

(c) Example of an operation guide

Figure 2: Phase One prototype

## 5.2 Phase Two - Part A

E-Learning modules will be at the heart of Fishing's app with most users being healthcare workers. Phase two will extend the E-Learning interface and architecture for operation modules. Where the extension of maintenance modules will be added once the second level of safety has been reached in phase 3 (See Appendix G - Figure 22). Operation modules for more equipment will be made and all modules will be extended to additionally include learn as you go videos. These videos will be made by local from their country rather than someone from the developed world. Including the locals throughout the developmental process, we hope to not only create a more culturally inclusive product but foster a higher rate of acceptance. As part of the EWH program, staff and students from Makarere University have agreed to help develop instructional videos as well as training material. The development of a patient inventory system Stre@mline in South Western Uganda also stresses the importance of including locals in the design process [17] (See Appendix E). To ensure the validity and accuracy of the operational material provided, we will consult with industry professionals and academics. Furthermore, by consulting with these individuals and organisations, materials such as service manuals can be acquired to help the development of learning material. This high-level approval is part of the second level of safety from our safety plan (See Appendix G - Figure 18).

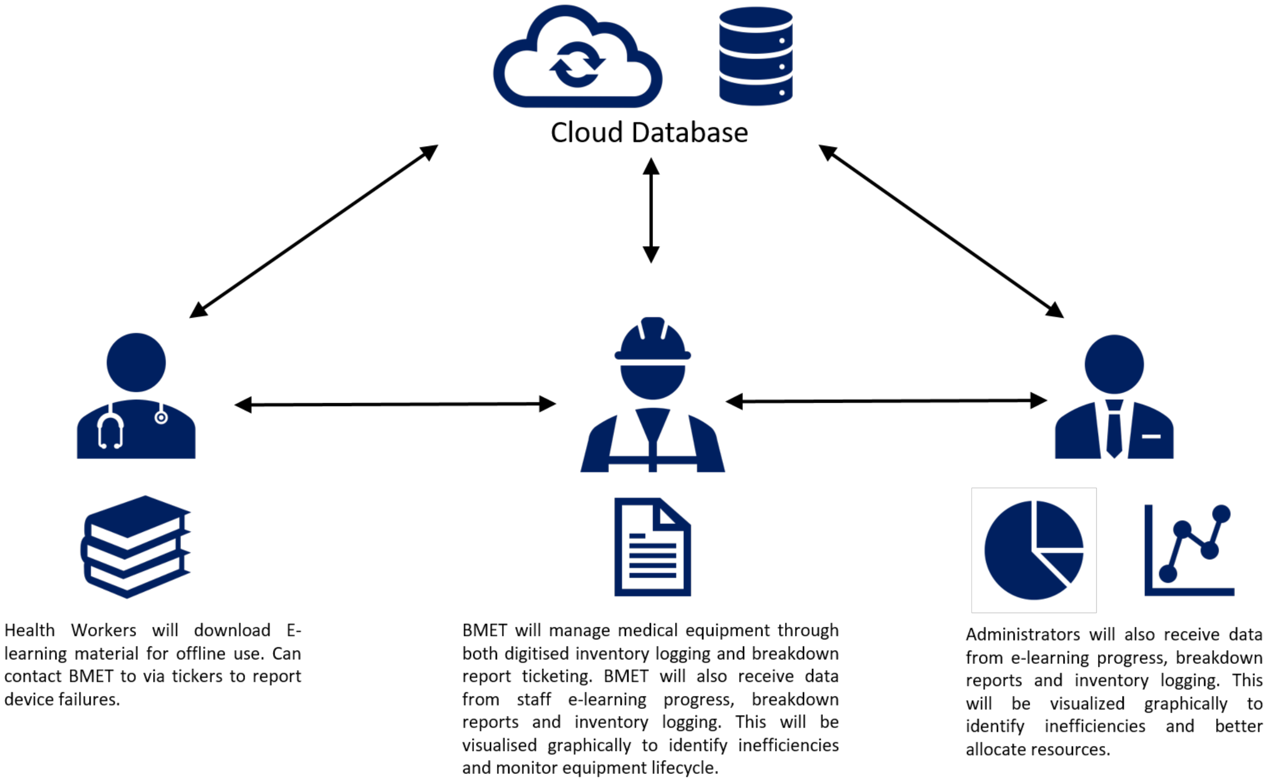



Figure 3: Fishing platform system overview - High level diagram of how the different features discussed in phase two parts A and B will interact between different users. Fishing will have three interfaces, an app for healthcare staff using medical equipment, an app for equipment management by the BMET and cloud-based software for hospital administration

## 5.3 Phase Two - Part B

This phase will consist of building and updating the original minimal viable product to include medical equipment management functionality. The inventory management capability of Fishing will allow healthcare workers to report issues with medical devices by sending a ticket via the app to the hospital's BMET (See Figure below).

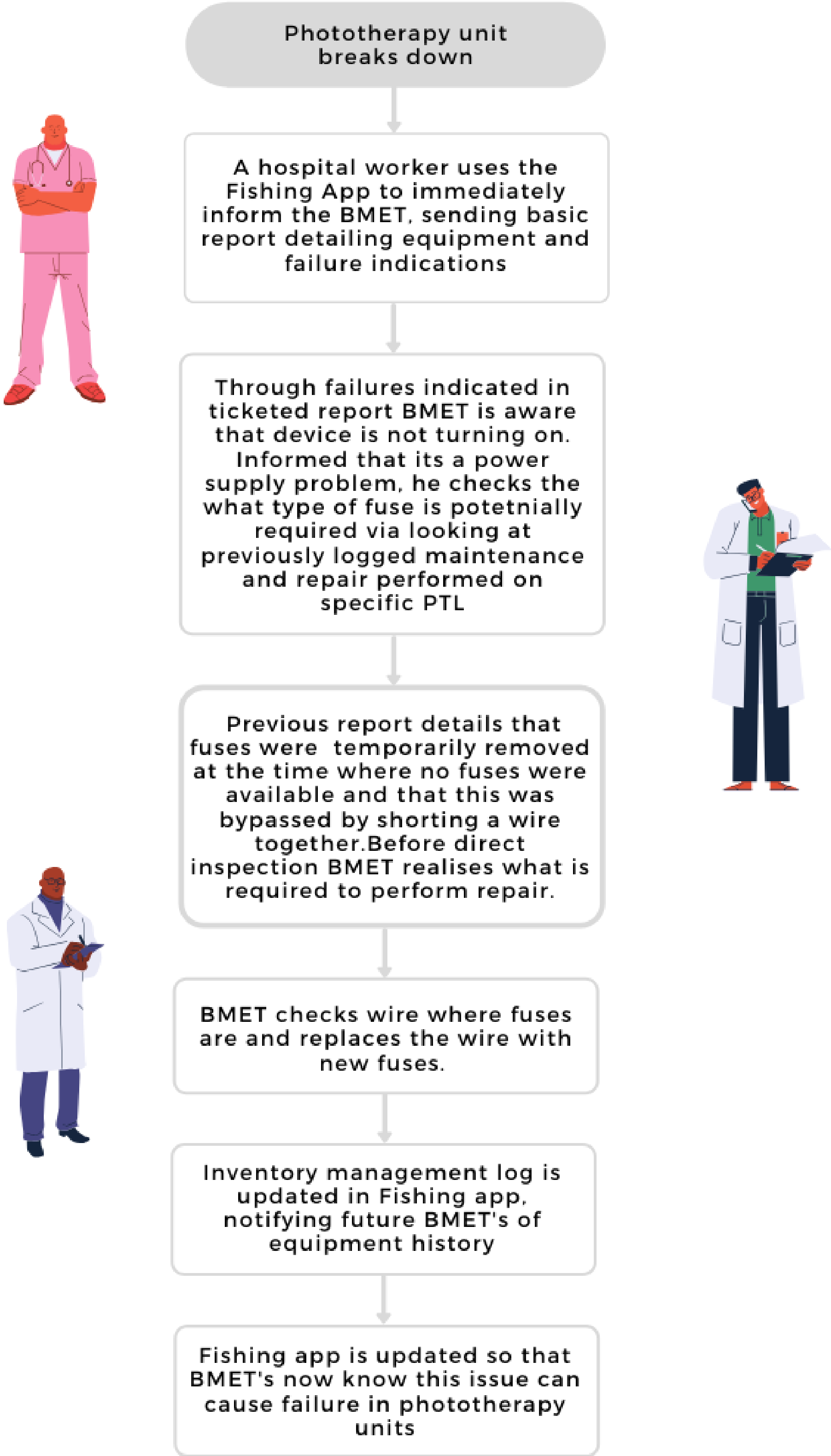



Figure 4: Using Fishing for reporting device failure

The hospital administrator will be provided with a web application that combines the analytics of data collected from within their healthcare facility. This collected data will be fed from user training, breakdown reporting and inventory. Combining medical equipment data with user training will additionally enable visualisation of user-experience with medical equipment. Showing where training is being neglected and additional training may be required. Amazon Web Services will be used to store all data and create an analytics dashboard. This dashboard will use algorithms to allocate the incoming data into an easy to interpret user interface with visual graphs, charts and tables. This web-based application will allow administration along with remote third parties to analyse data, visualise total oversight, set goals and better allocate resources in the future.

A major part of implementing this next feature will be establishing that healthcare workers do not have reasonable access to 3G/4G networks, a P2P mesh network may be introduced to provide inter-hospital communication with all health care workers completely offline. See the appendix for a full breakdown of all possible configurations and how that will impact the performance of Fishing. Finally, at the completion of phase 2, an e-learning validation study will be performed in order to reach the third level of safety from a safety plan (See Appendix G - Figure 18)

## 5.4 Phase Three

Once validation study is successful and healthcare workers safety is ensured, maintenance modules will be added to the e-learning feature. Conclusive evidence will have been gained to whether 3G/4G technologies can or cannot be relied upon. This will then determine if building a P2P mesh network needs to be built or if Fishing can be released as is. Once this is released further user-testing will be performed and improvements made where necessary. Monitoring the data collected over a particular period of time will be useful to then begin marketing the data.

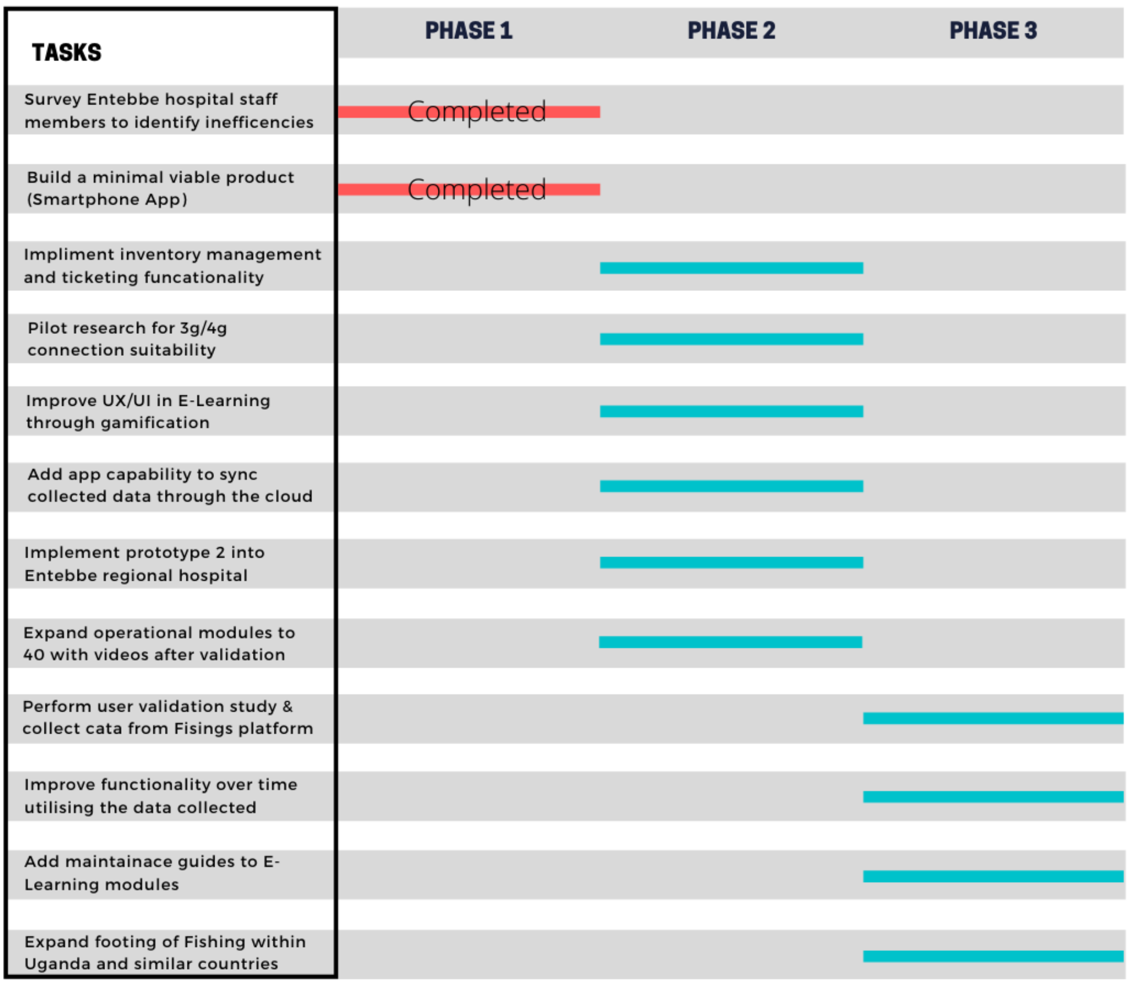



Figure 5: Gantt chart - Key tasks and objectives for each phase

# 6 Proof of Performance

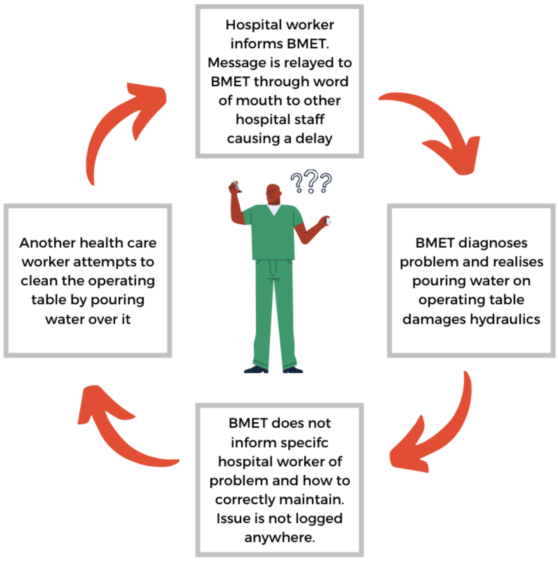
Fishing's digital E-Learning platform will be a significant improvement to the current methods employed around the developing parts of the world. Where only 9% of staff surveyed at Entebbe Hospital said they received training yearly and 32% had last received formal training during traditional education (See Appendix B). All staff mentioned that they believed further training was necessary, with all wanting to participate if it was provided for free. End users see the benefit, and very little have access to user training, that needs to change. Not only will Fishing's E-Learning platform be free to end-users, but also consciously designed to consider the end-users environment. Furthermore, the list of features inherent to Fishing's gamification model creates an engaging method of user training [18], (See Appendix F).

## 6.1 Impact of Fishing

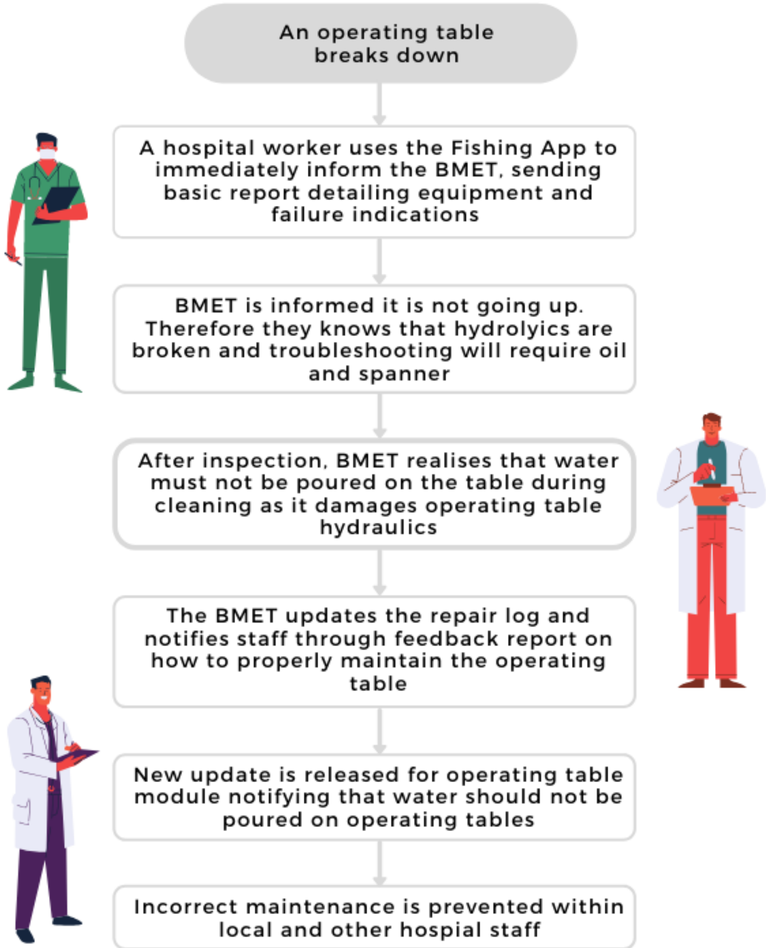
A lack of modern technology means healthcare facilities in developing regions rely on analogue technologies such as printing instructions on a piece of paper and sticking it next to a machine (See Appendix D). These instructions present certain challenges in that they are often too general, incorrect or misleading and are inconsistent across different hospitals. The administration workers who are often responsible for creating standard operating procedures often themselves lack correct user training and appropriate knowledge on medical equipment. In healthcare facilities with minimal staff, there may be a complete absence of any standard operating procedures. Fishing provides a system whereby standard operating procedures regarding the use of medical devices are reliable and verified by professionals. Furthermore, accessibility is greatly improved as all healthcare workers will have easy and immediate access to the correct information. Fishing does not assume prior technical knowledge for learning the modules and will have options to learn information in the healthcare worker's local language. Because an app is easy up-dateable, appropriate e-learning modules can be added over time, giving healthcare workers the capacity to maintain a good standard knowledge base which is continuously improved and developed.

Fishing's ERP based equipment management system replaces current analogue methods of recording inventory (See Figure 20 in Appendix D). The use of a paper-based system presents an arduous task which is difficult to be tracked over periods of time. Recent experience collecting inventory this way within multiple Ugandan hospitals during an outreach program by Engineering World Health's in 2019/2020 proved its difficulty. Despite best efforts without capable oversight, with the large amounts of unorganised and often untraceable equipment, many pieces of equipment were unaccounted for or neglected. The introduction of Fishing's QR code-based inventory management system will allow for BMETs to easily record inventory through an intuitive user interface. Furthermore, the use of computers and smartphones will digitise the current analogue method allowing for oversight of equipment life-cycle within and between facilities. This will allow effective equipment allocation and increases workflow. Thus strengthening healthcare services. This also presents the advantage of more efficient data collection which in the long term will better inform future solutions for improving the interaction of healthcare workers with medical equipment e.g. knowledge on which types of equipment is least operable will inform improved equipment design.

Currently, there are no standardised systems for reporting broken equipment within a healthcare facility. Repairs of equipment failure are prolonged due to solely depending on word of mouth and that BMET usually has to initially troubleshoot the equipment before the problem is eventually recognised. Often the equipment is repeatedly broken as temporary fixes are not accounted back to and healthcare workers are not made aware of equipment problems or how to avoid them in the future. Fishing's breakdown reporting feature will reduce the time it takes for a repair to be carried out and will plug circular repeated equipment failures (refer to Figure 6 below).




(a) Current method for reporting medical device failures. Creates a circular problem




(b) Fishing's method for reporting and resolving medical device failure

Figure 6: Scenario - Flow chart comparison between existing and proposed system. Example of how Fishing will perform.

# 7 Business Plan

## 7.1 Cost of Development

The development of the Fishing App platform presents no major cost as the majority of the software will be written by our team. All information will be backed up onto a cloud storage system. Leveraging Amazon Web Services Relational Database Storage (RDS) system will provide a fast, secure and cost-effective means of storing all the collected data. Currently, the cost of general-purpose (SSD) storage is only $0.151 per GB-month.

The developing cost of producing E-Learning material will also be minimal. During this phase, we will be working with local Ugandans to create the material. As well as contacting medical equipment manufacturers for equipment guides.

## 7.2 Manufacturing/Development Plan

If users are found to have sufficient access to 3G/4G technology and we can release the platform without additional P2P network hardware. This will confine costs to any cloud solutions we employ. Fishing will be available via the internet, and will be designed to work offline as much as possible. E-Learning data will be cached whenever the user has access to the internet so the user does not have to continuously use the internet and can operate modules offline. Functions such as raising tickets will need to be performed over the internet. However, sending a ticket (reporting equipment breakdown) will be optimised to use the least amount of data as possible.

## 7.3 Scalability

Once the Fishing platform has been built the number of users it can reach is not resource-dependent and can easily be installed across Uganda and other developing regions. To promote Fishing's services we will work with outreach programs and existing partners (such as staff and students from Makerere University, and biomedical technicians in Cambodia). Working with partners and outreach programs will allow us to introduce Fishing to developing hospitals across multiple developing regions. These outreach programs already perform inventory collection and staff training. This makes them suitable for implement Fishing during their outreach as it would complement and improve current methods.

Apps systems can be updated and new versions easily introduced containing new features which may further improve the interaction between medical devices and health care workers. New features could include an extension to other areas such as e-health or disease tracking. Fishing will have these capabilities to ensure that the services offered can evolve to meet the changing needs of end users.

Finally, a result of Fishing's aim to directly addresses an objective of WHO in encouraging the implementation of a framework that ensures donations that are made will be useful to the donor country. Fishing has the potential capabilities to support the implementation of these policies (through monitoring the training, maintenance and providing reporting) which will be a required supplement for any future equipment donations.

## 7.4 Potential Selling Price

We plan to offer a pricing model that scales as more users are on board. This will be primarily used to cover the cost of storing each user's information, as well as funding the research and development of future E-Learning material. It will, therefore, cost US$1/per user per month, or US$12/per user for a year. This will provide access to ongoing support and the commitment of new E-Learning material. Whilst hospitals will be funding their services on a pro-rata basis, we also aim to sell data to organisations such as governments, biomedical companies and NGOs.

## 7.5 Demand

Gathering data relating to medical equipment management can provide new ways for governments and international organisations to better distribute health technology resources to those who need it the most, and where it will be most utilised. Some projections indicate that the global internet of medical things is expected to increase to $158 billion by 2022, a $41 billion increase from 2017 [19]. This shows the growing industry and how demand for such data could be beneficial to biomedical companies to understand how geographic and demographic attributes affect the life-cycle of a device. As such, this could lead to informative innovations in developing devices that are suited for both developing and the developed world.

## 7.6 Target Market and Sales Forcast

Since our initial pilot began in Entebbe, Uganda we will use that as a base to determine the amount of health care workers. In 2014/15 it was reported that 81982 workers were employed in the health sector [20]. If we were to capture at least 75% of the health sector here, that would present revenue of just under US$740,000 directly from hospitals based on the pricing model above. Furthermore, whilst hospitals will have access to their individual inventory, we will be able to identify medical devices problems across 75% of all hospitals accurately. Utilizing big data practices, it will be easier to identify systematic problems in the health care sector, which will be of use to health policy analysts and officials in Uganda. Once it is established that Fishing is capabilities in improving accessibility to medical equipment, Fishing can be extended into neighbouring East African countries. Prices for selling data will have to be negotiated with officials, as to how the data is interpreted and used is where value is derived when compared with simply selling large datasets at a specific rate.

## 7.7 Distribution

The application itself will be available on the Google Play Store and Apple App Store. To restrict access to users, administrators will be required to provide a list of all users in the hospital. We will then provide users with unique identifications numbers and passwords which they will use to login and then change the password to their liking. To ensure a high level of security, users will initially need internet access to register their accounts for the first time. Administrators will be able to set up an account through our website, and this will be valid for each hospital. If users are not able to access the Playstore/Appstore, we will be able to transfer directly in person during initial installation and training.

## 7.8 Plan for Copyright/IP

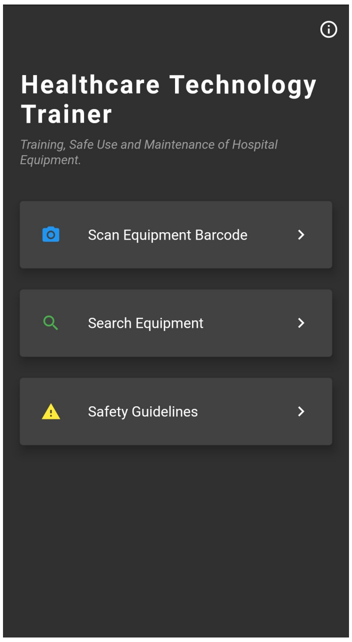
We will seek out copyright to protect the E-Learning material that is published through Fishing. A patent search on similar technologies was done. This found some similar platforms focused on E-Health systems but to our knowledge, there are no existing patents for a platform that combines e-learning with ERP for medical equipment management.

## 7.9 Regulatory Requirements

Since there are no government regulations, independent accreditors or funding mechanisms established to regulate a product like Fishing, we will aim to use international guidelines, industry benchmarks and professionalism to self-regulate the app and its content. During development self-regulation such as the safety plan (refer to Appendix G) will be considered. Before publishing guides, we will have industry and academic professionals ensure the validity of our E-Learning material. We will also develop a standard within this regulating community that Fishing will adhere to. To ensure users are aware of the E-Learning material, quizzes and disclaimers will be embedded in the app. These will be prompted for all devices and will ensure users understand the risks involved with medical devices.

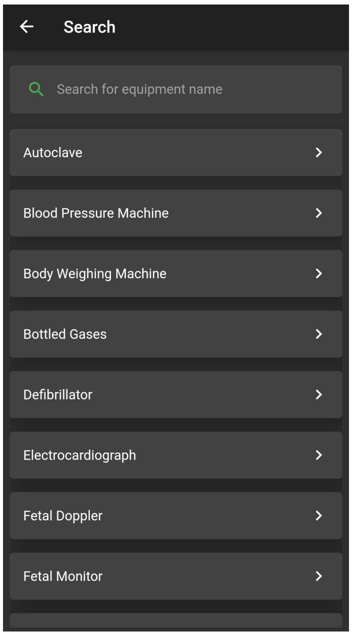
To ensure that regulations are adhered to surrounding the nature of data collection, we will be using AWS cloud infrastructure since it complies with the European Union's General Data Protection Regulation (GDPR). Furthermore, end-users will be provided with disclaimers noting that their data may be used for commercial purposes.

# Appendix A Phase One Prototype

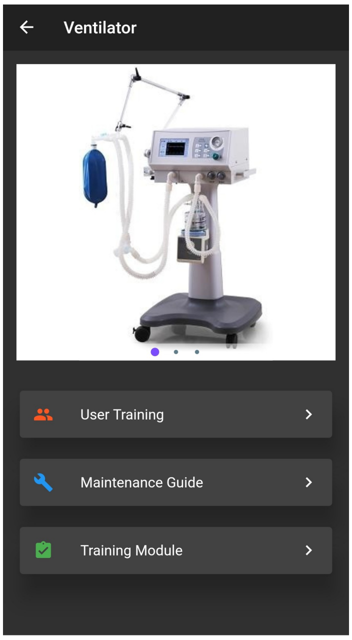



(a) App Home Page

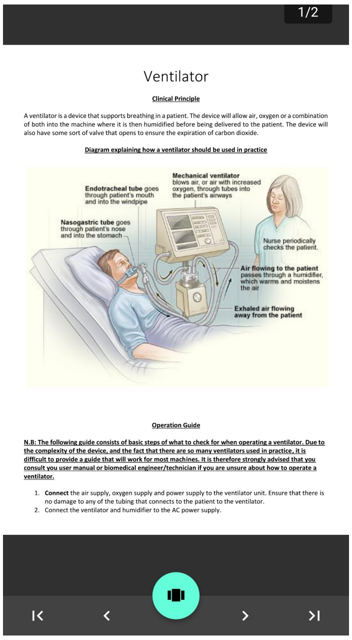

(b) Scanning of QR Codes



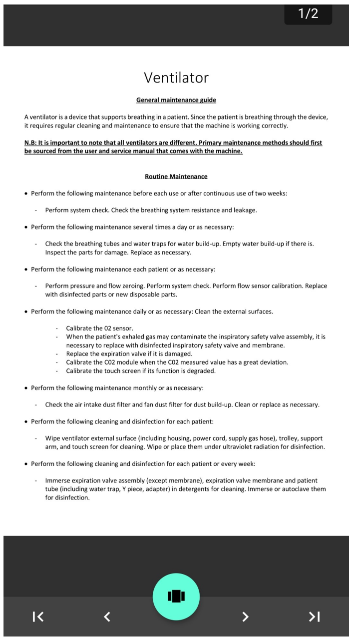

(c) Search Modules



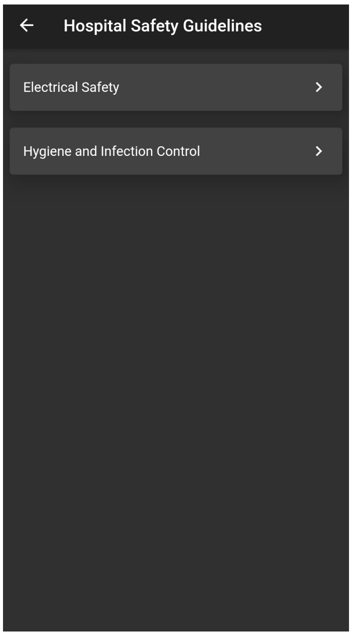

(a) Ventilator Module




(b) Ventilator Clinical Principle PDF




(c) Ventilator General Maintenance Guide PDF




(a) Hospital Safety Guideline Modules


Hygiene and Infection Control

*Preventing the spread of infection in hospitals*

For both patients and hospital staff alike, germs must be destroyed in order to prevent the spread of infections. Incorrect sterilisation and inadequate disinfection of medical equipment can have devastating and lethal consequences on patients. Lapses can lead to outbreaks of HIV, hepatitis B and C, and the transmission of bacterial-infecting agents. Luckily, most sterilisation and disinfection procedures are straight forward to learn and applying them into your daily routine is simple. Anyone who works in a hospital or healthcare centre are responsible for maintaining and protecting each department they work in by performing correct sterilisation and disinfection techniques. Adherence to these disinfection and sterilisation practices will reduce infections spreading between patients as well as protect yourself and your co-workers.

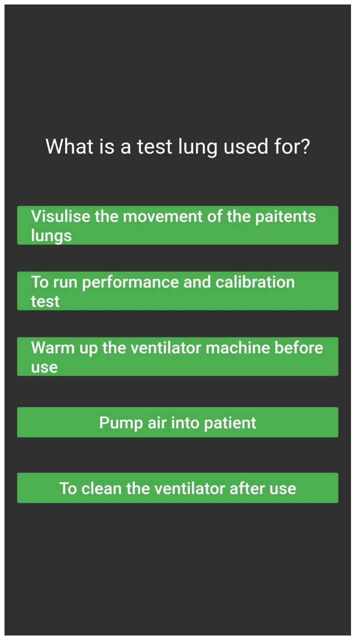
**Source of Infection**

In a healthcare facility the source of infection and result of contamination occurs from the staff, the patients or the hospital/health centre environment. Having good personal hygiene, following correct patient and equipment handling and keeping your department environment sterile will reduce the spread of infection.

Table 1: Examples of pathogens which may contaminate the hospital environment:

| Source | Pathogen |
|---|---|
| Food<br>Community outside hospital (water system) | Salmonella , Shigella spp., Escherichia coli |
| Air Conditioner | Legionella pneumophilia, causing Legionnaires' disease |
| Compromised Pharmaceuticals | Pseudomonas aeruginosa, Burkholderia cepacia, or Serratia marcescens |
| Nasal passage | Staphylococcus aureus |
| Feces | Enteropathogens such as Salmonella spp. |
| Symptomless carriers (patient or staff ) | Streptococcus pyogenes, Corynebacterium diphtheriae, Neisseria meningitidis, hepatitis B virus, and cytomegalovirus. |

(b) Hygiene and Infection Control PDF




(c) Training Quizzes

# Appendix B Data collected at Uganda Regional Referral Hospital

A group of 46 hospital staff at the Uganda Regional Referral Hospital were surveyed to gather the following data below (note some surveys were lost and not returned). The survey conducted ensured that staff from all departments at the hospital were included. All of these surveys were conducted with the permission of the Entebbe Hospital. Proof of documentation can be provided on request.

The staff were surveyed were from the following departments -

| **Department** | |
|---|---|
| Pedatric ward | 2 |
| Male ward | 7 |
| PAC | 1 |
| Maternity | 1 |
| Orthopedics | 8 |
| Dental | 2 |
| Casualty | 3 |
| Early intervention | 2 |
| NICU | 4 |
| Operating theatre | 8 |
| General | 1 |
| Gyno | 6 |
| OPD | 2 |
| Dental | 2 |
| Female ward | 2 |
| General | 1 |
| Casualty | 3 |
| Total | 46 |

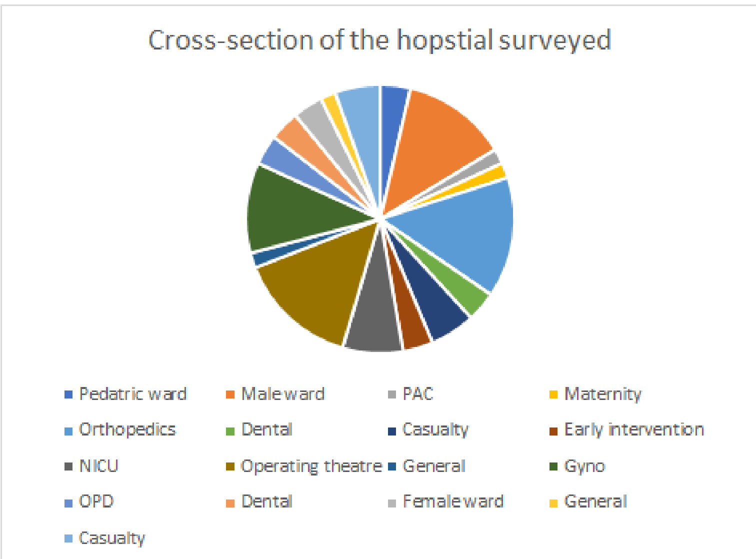



Figure 7: Cross Section of the hospital staff surveyed

## B.1 Survey Questions & Collected Data

The graphs and the tables below shows the data collected after conducting the survey.

**1. How often would you perform maintenance?**

| | |
|---|---|
| Never - its not my job | 10 |
| Daily | 16 |
| Weekly | 5 |
| Monthly | 1 |
| Yearly | 2 |

**2. Do you own a smart phone (touch screen phone) which can take photo?**

| | |
|---|---|
| Yes | 30 |
| No | 4 |

**3. Do you know how to download an app?**

| | |
|---|---|
| Own a smart phone and know how to download an app | 30 |
| Don't own a smart phone and can not download an app | 3 |
| Don't own a smart phone but can download an app | 1 |

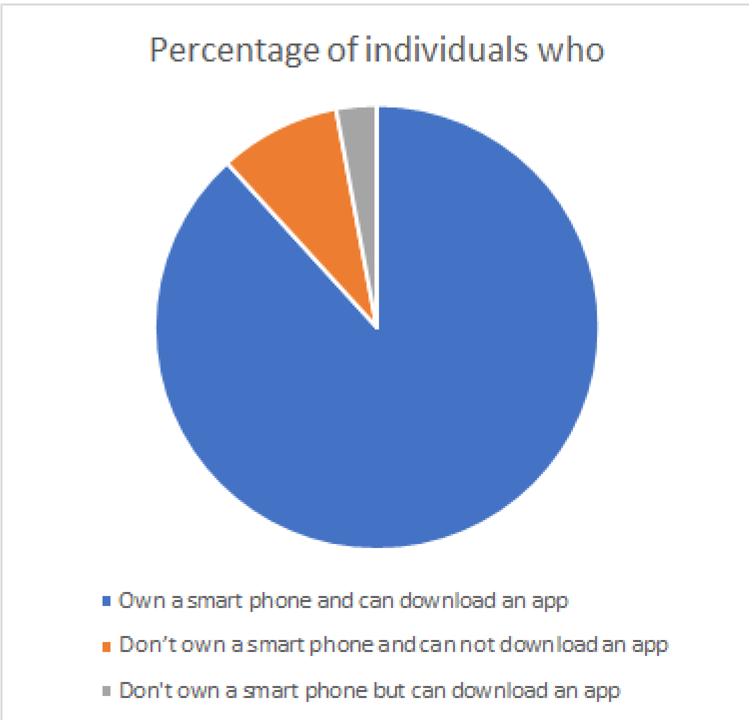



Figure 8: Percentage of staff who know how to download an app

#### 4. Tick the following which you find a good way of learning?

| | |
|---|---|
| Video tutorial | 19 |
| Step by step guide | 17 |
| Quiz | 2 |
| Pictures/Photos | 5 |
| Practical Learning | 1 |

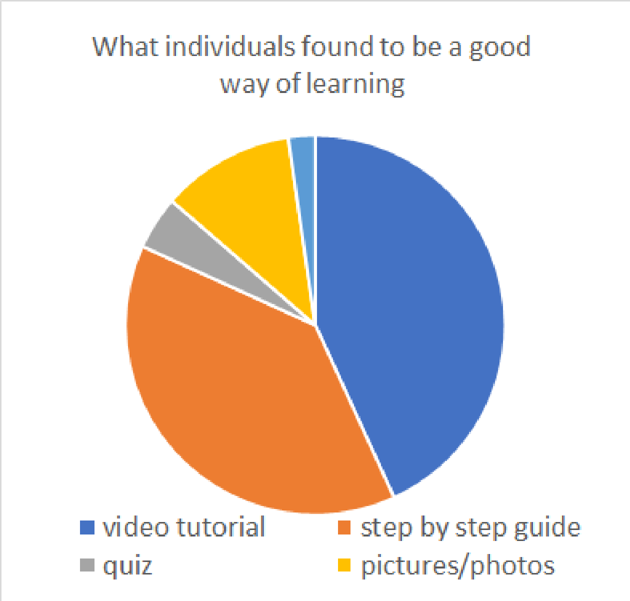



Figure 9: What individuals found to be a good way of learning

#### 5. How often do you use the following equipment (tick only one for each item)?

| | Never | Sometimes | Often |
|---|---|---|---|
| Ventilator | 14 | 8 | 12 |
| Oxygen Concentrator | 7 | 14 | 13 |
| Electrocardiograph | 32 | 2 | |
| Blood Pressure Machine | 3 | 12 | 19 |
| Pulse Oximeter | 9 | 7 | 18 |
| Defibrillator | 27 | 7 | |
| Fetal Monitor/Fetal Doppler | 21 | 6 | 7 |
| Infant Incubator | 18 | 7 | 9 |
| Weighing Machine | 4 | 10 | 20 |
| Infant Warmer | 23 | 5 | 6 |
| Phototherapy Lights | 20 | 8 | 6 |
| Respiration Rate Meter | 23 | 6 | 5 |
| Suction Machine | 14 | 11 | 9 |
| Theatre Lamps | 19 | 12 | 7 |
| Anaesthesia Machine | 23 | 5 | 6 |
| Bottled Gases | 28 | 4 | 2 |
| Hot Air Oven (Steriliser) | 17 | 9 | 8 |
| Autoclave | 5 | 15 | 14 |
| Patient Monitor | 21 | 9 | 4 |
| Operating Tables | 15 | 9 | 11 |
| Dental Chairs | 21 | 7 | 6 |

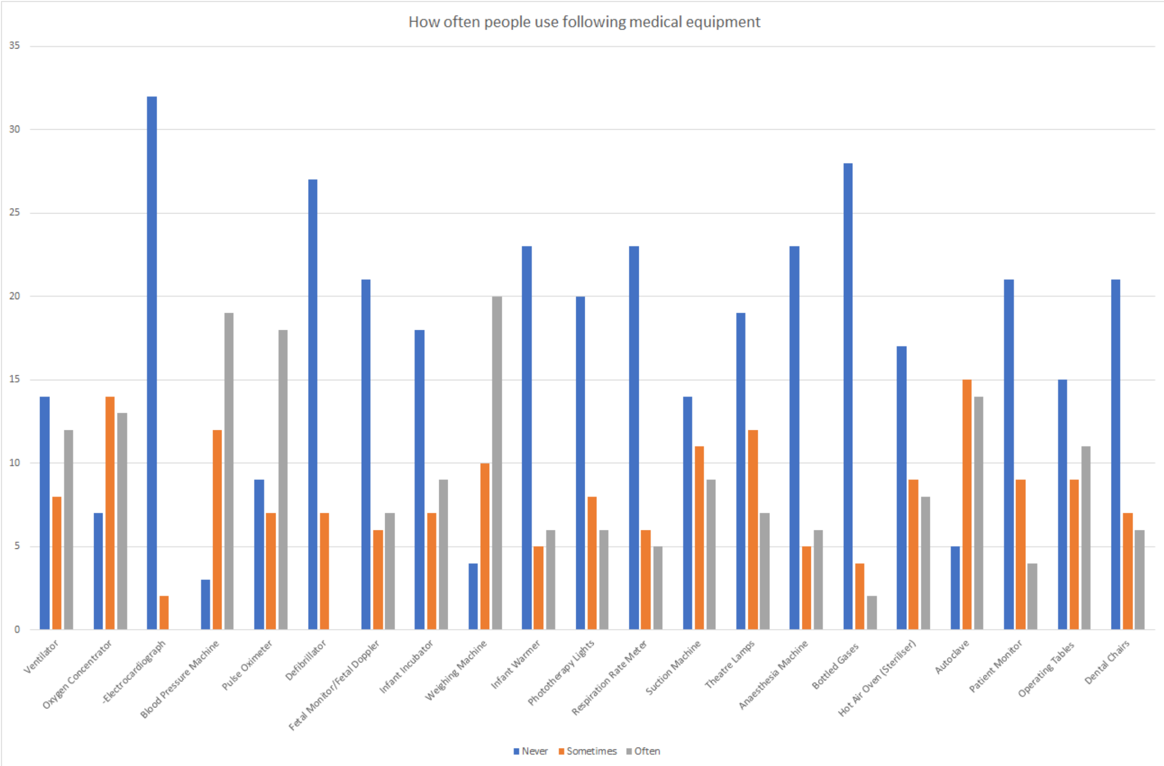



Figure 10: How often people used various medical equipment at the hospital

**6. How well do you know how to use the following equipment (tick only one for each item)?**

| | Not at all | Can try (fairly) | Perfectly |
|---|---|---|---|
| Ventilator | 13 | 10 | 11 |
| Oxygen Concentrator | 6 | 15 | 13 |
| Electrocardiograph | 28 | 5 | 1 |
| Blood Pressure Machine | 1 | 5 | 28 |
| Pulse Oximeter | 5 | 6 | 23 |
| Defibrillator | 21 | 12 | |
| Fetal Monitor/Fetal Doppler | 23 | 3 | 8 |
| Infant Incubator | 22 | 3 | 10 |
| Weighing Machine | 2 | 4 | 27 |
| Infant Warmer | 21 | 6 | 8 |
| Phototherapy Lights | 25 | 4 | 5 |
| Respiration Rate Meter | 20 | 8 | 6 |
| Suction Machine | 13 | 7 | 14 |
| Theatre Lamps | 18 | 5 | 11 |
| Anaesthesia Machine | 25 | 4 | 5 |
| Bottled Gases | 28 | 5 | 2 |
| Hot Air Oven (Steriliser) | 15 | 9 | 10 |
| Autoclave | 6 | 13 | 15 |
| Patient Monitor | 19 | 7 | 8 |
| Operating Tables | 20 | 7 | 10 |
| Dental Chairs | 20 | 6 | 8 |

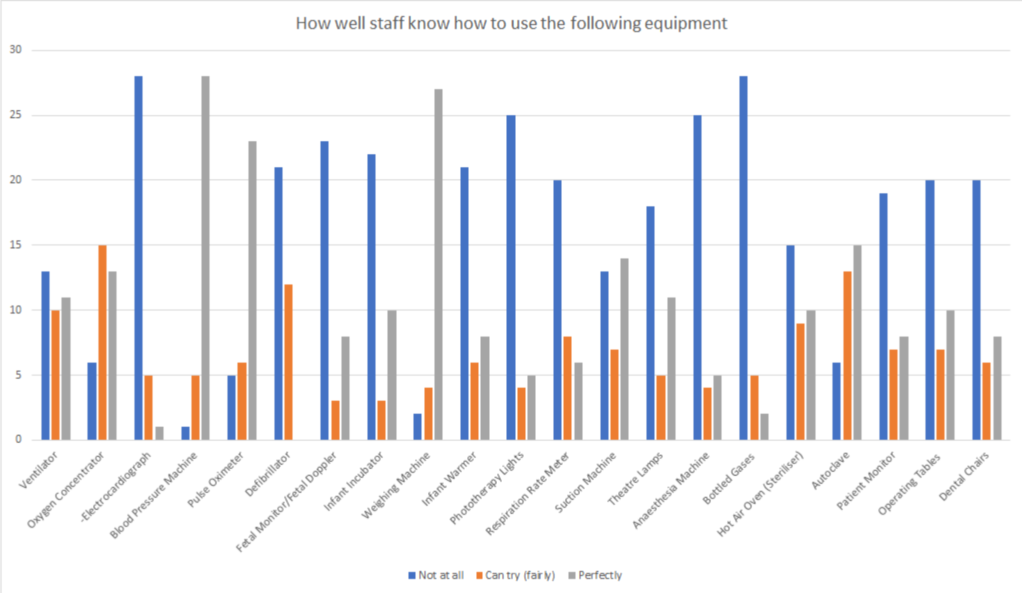



Figure 11: How well the staff knows how to use various equipment

### 7. What are the biggest challenges with medical equipment in the hospital?

| | |
|---|---|
| Inadequate materials/drugs | 7 |
| Inadequate equipment | 8 |
| No implementation | 2 |
| Long service duration | 1 |
| Shortage of equipment | 12 |
| Equipment not maintained | 5 |
| Equipment overused | 1 |
| Repair only done when damage is done | 1 |
| Lack of staff | 2 |
| Lack of user knowledge/training | 8 |
| Machines are complicated to use | 3 |
| Training not given to everyone | 2 |
| Machine outdated | 2 |
| Electricity | 1 |
| Out of service | 1 |
| Lack of spare parts | 1 |

### 8. Times received formal user training

| | |
|---|---|
| Never | 8 |
| Once | 9 |
| 2-5 times | 3 |
| Yearly | 3 |
| During schooling | 11 |

### 9. Do you believe further training on the use and maintenance on medical equipment is necessary?

| | |
|---|---|
| Yes | 34 |
| No | 0 |

# Appendix C Phase Two UX/UI Implementation

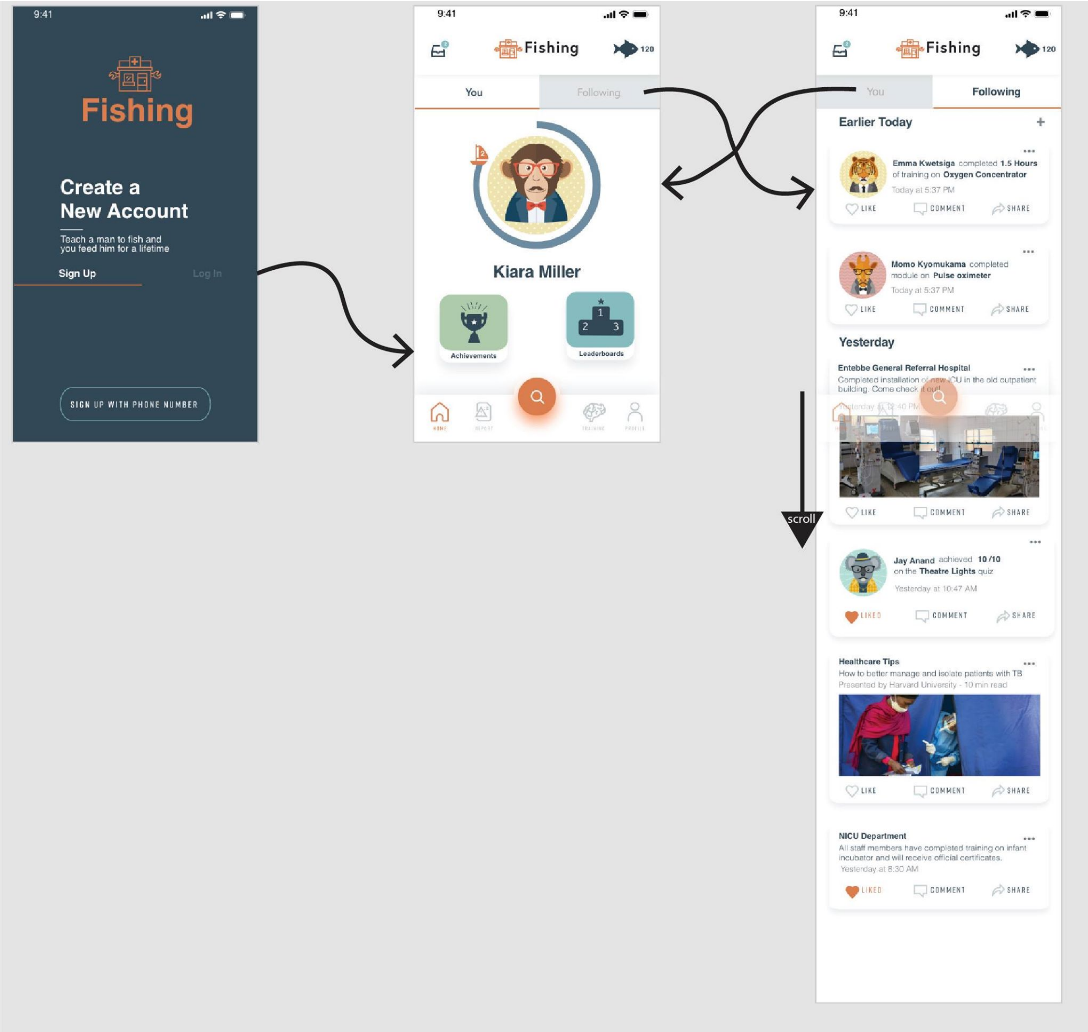



Figure 12: User profile and feed

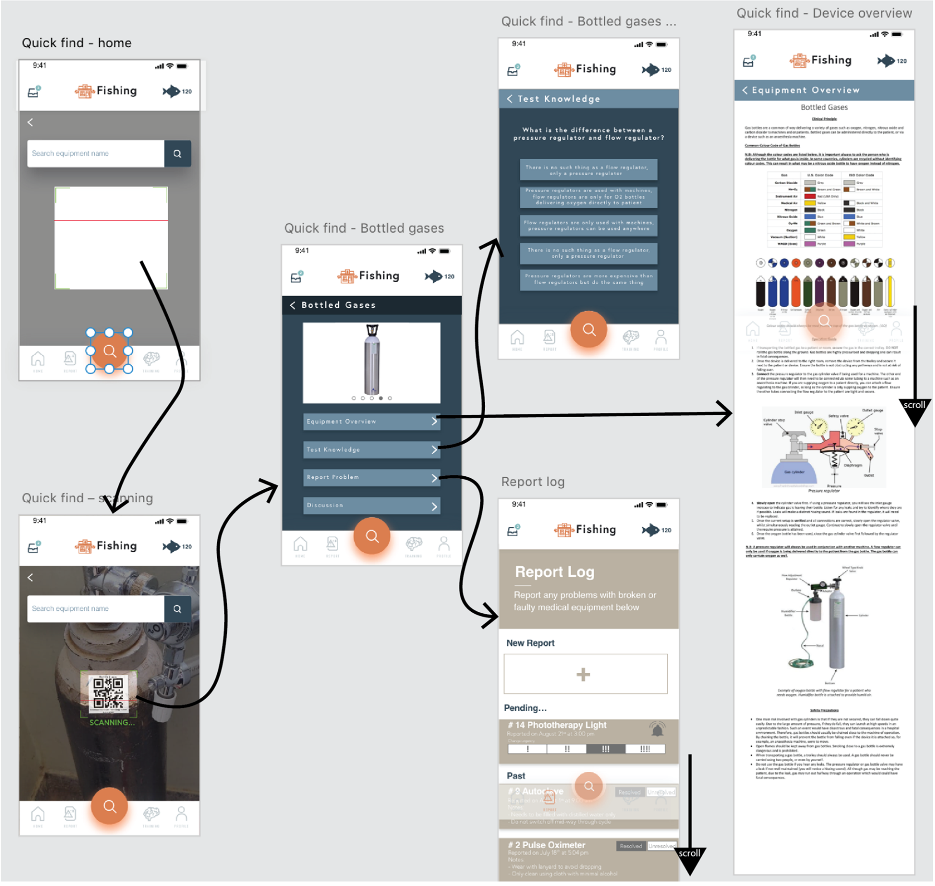



Figure 13: Scanning of QR code, attempting E-Learning module

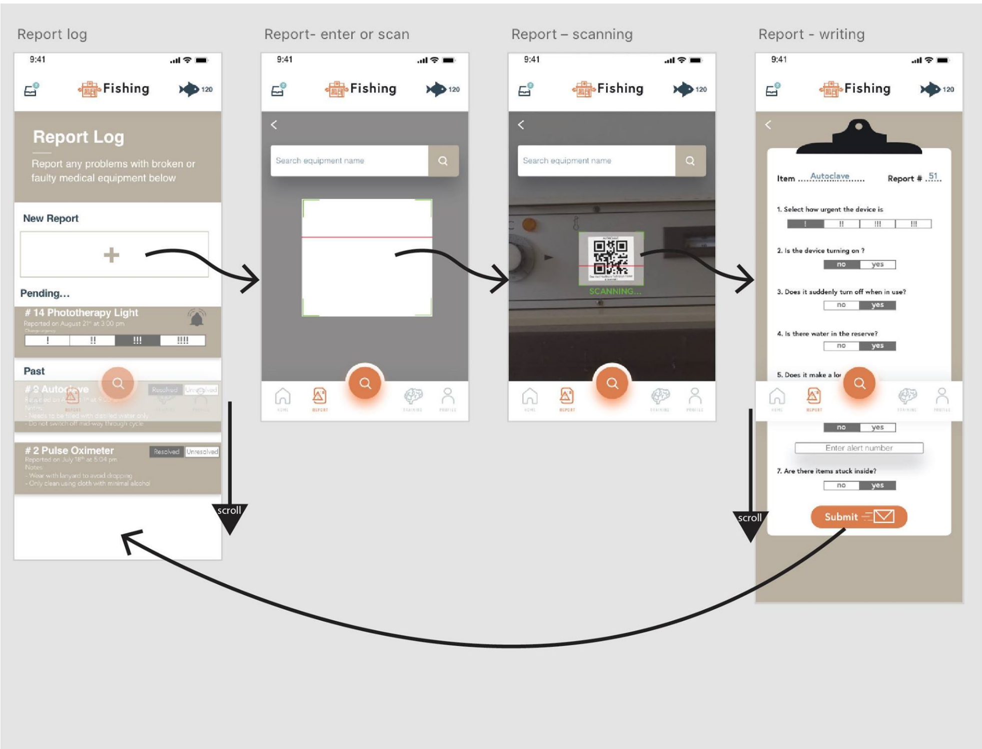



Figure 14: Reporting issue

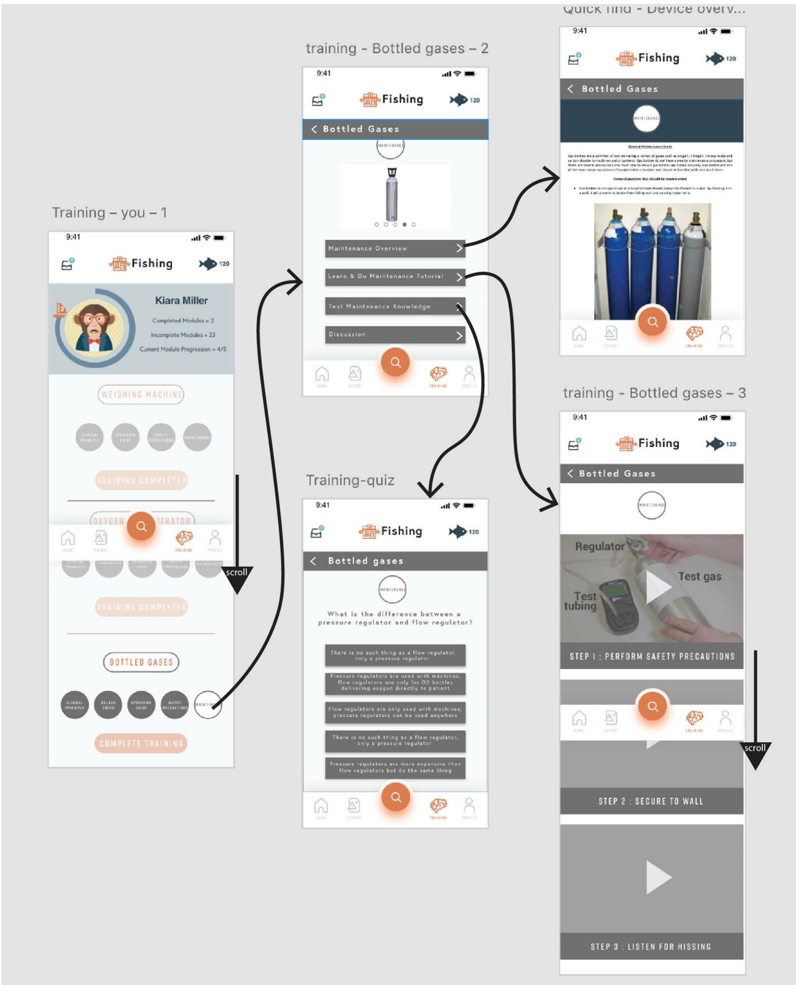



Figure 15: Training Module In depth

# Appendix D Existing Technologies

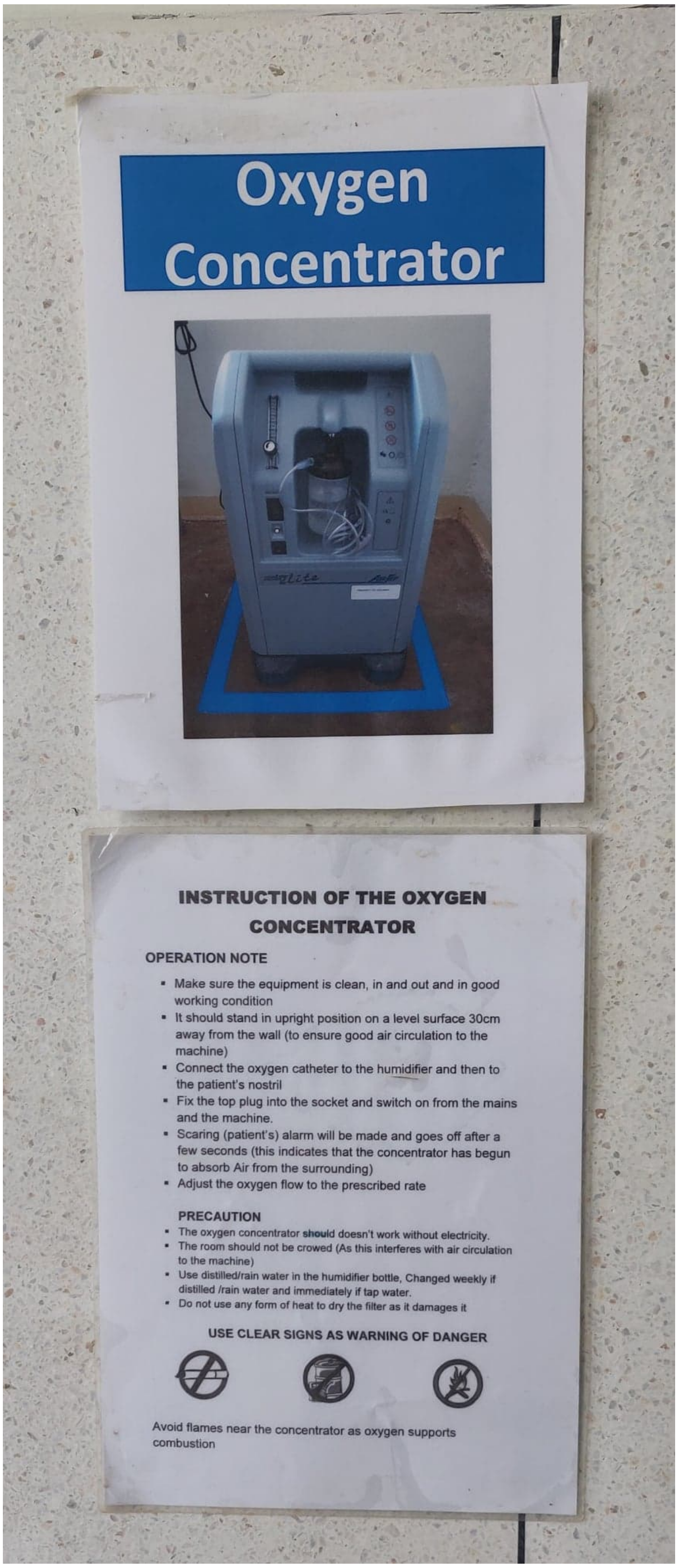



Figure 16: Standard operating procedure for Oxygen Concentrate

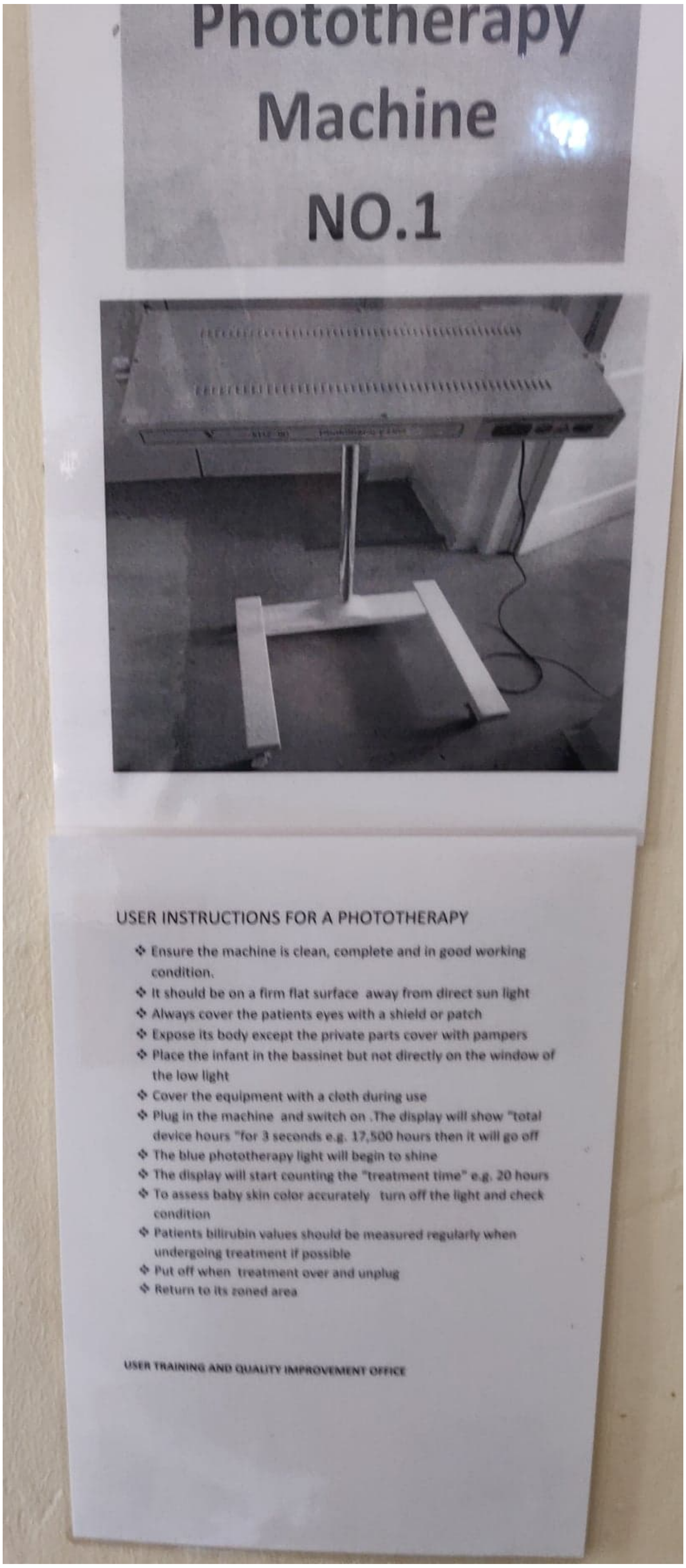



Figure 17: Standard operating procedure for Phototherapy Machine

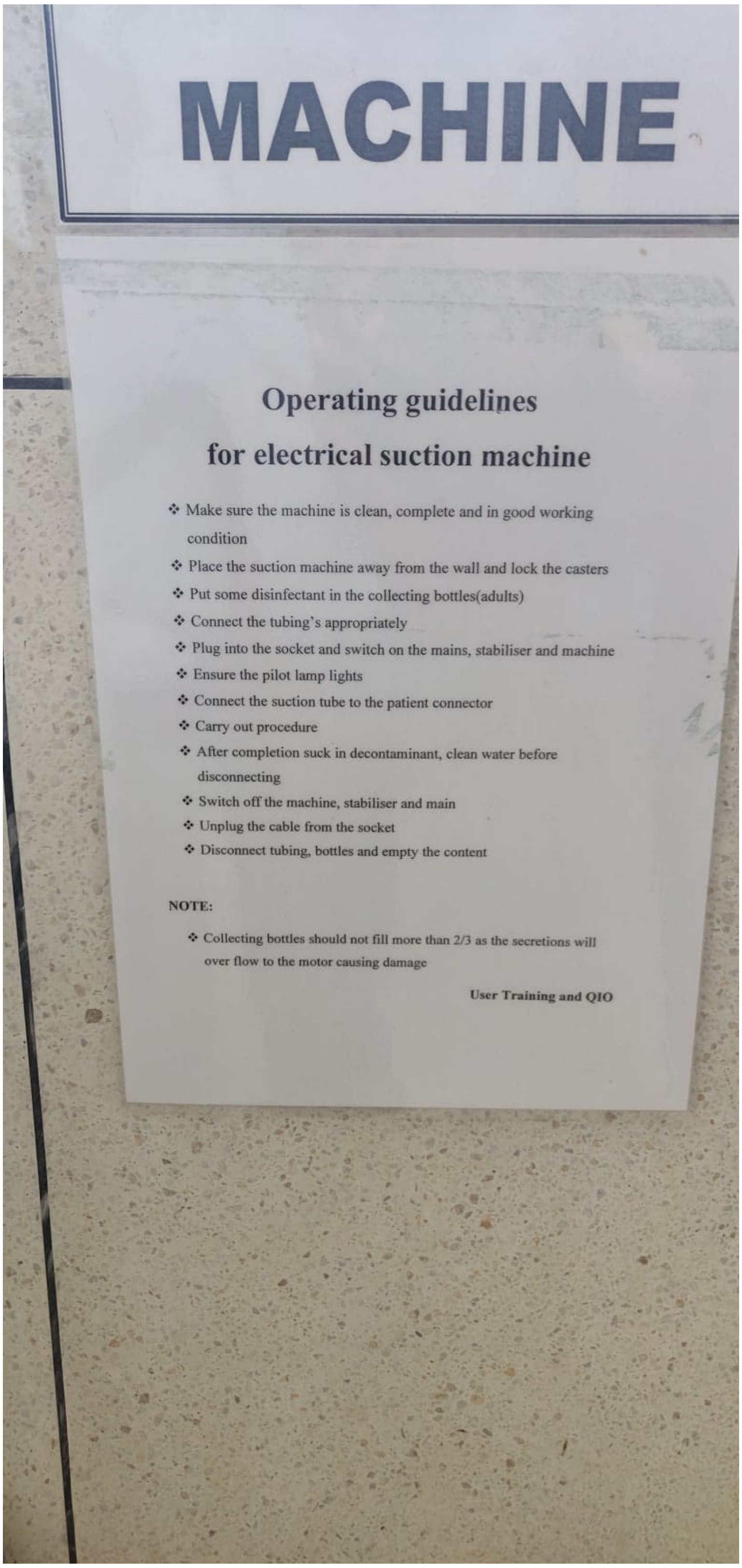



Figure 18: Standard operating procedure for Electrical Suction Machine

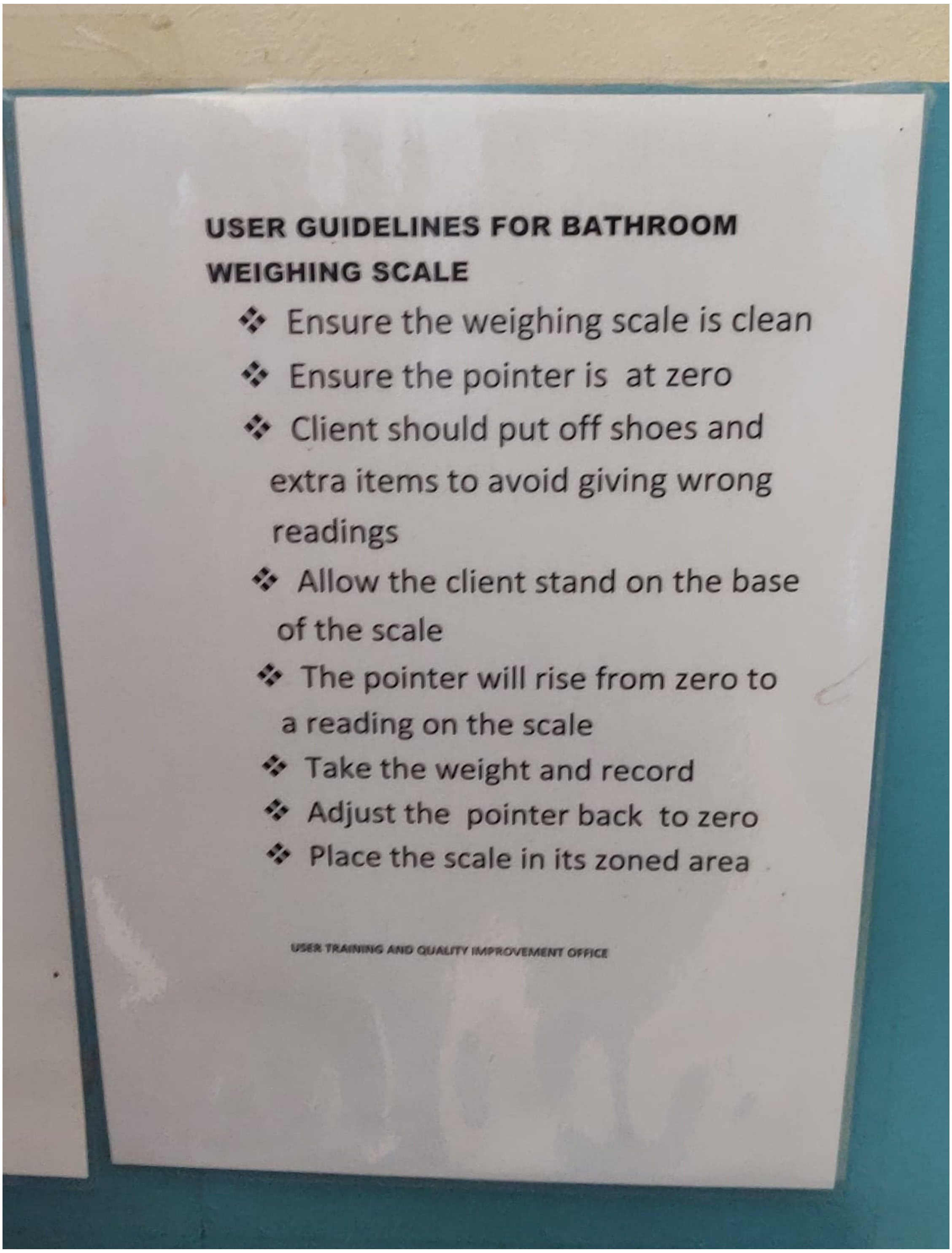



Figure 19: User Guidelines for bathroom weighing scale

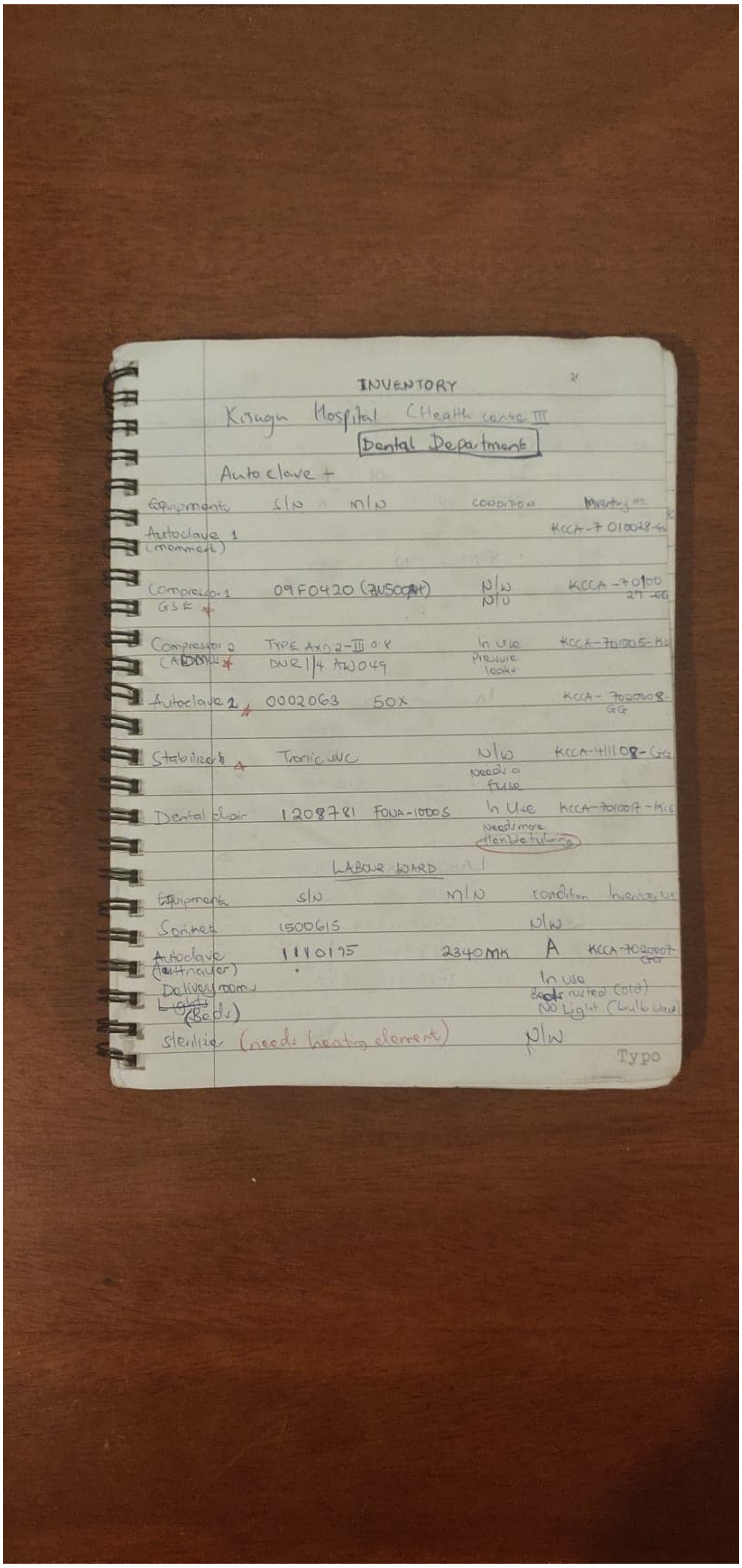


Figure 20: Manual recording of inventory

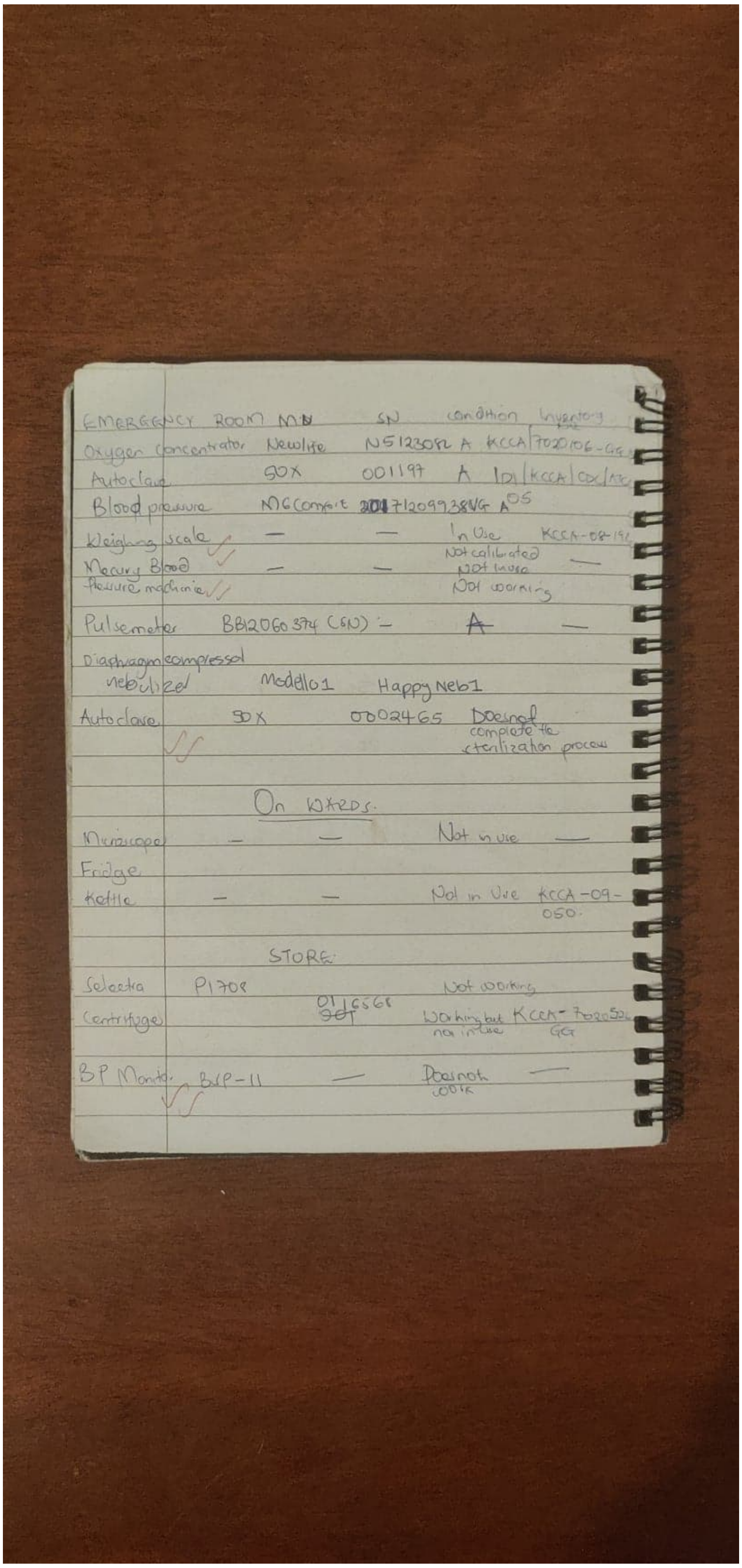


Figure 21: Manual recording of inventory

# Appendix E Existing Competitors/Solutions

Fishing's approach of using information technology to track, collate and report data as well as provide informational services via E-Learning is a common practice used in the developed and emerging economies.

E-Learning systems have proven to provide a new and effective means of training that encourages productivity and reduce running costs[21]. E-Learning platforms have shown that users retained up to 70% of information due to a more tailored experience when compared to traditional classroom environments where users on average retain up to 20% of information over six weeks. E-Learning is also more flexible, motivational and allows for the progress of Health Care workers to be more accurately monitored. In 1996, the Malaysian Ministry of Health introduced the "Continuous Medical Education" program which aimed to ensure healthcare workers were up to date on new methods, practices and technologies even after formal tertiary education[21]. The project, however, was plagued by the fact that in-person training facilities presented high costs and health care workers were provided with little flexibility in regards to how they could receive such training. As a result, the Malaysian Ministry of Health decided to shift the delivery of training to an online E-Learning model. This allowed the knowledge base of health care workers to be more consistent and made the information readily available to all health care workers. Furthermore, it allowed officials to more accurately identify and improve training material, leading to better health outcomes. There are many web-based E-Learning materials available covering medical devices [22],[23], however, these are expensive and don't consider needs or the environmental context of health care workers in the developing world. By simply re-routing foreign E-Learning material to the developing world, similar challenges seen in equipment donations such as ineffective communication and assumed knowledge would likely arise. Existing E-Learning material is overly technical, impractical and expensive in the context of the developing world.

Inventory Management and reporting is a common practice in the developed world, with many large companies and organisations employing Enterprise Resource Planning tools to monitor their supply chains and improve workflow. In particular, these tools use data to identify inefficiencies which can be rectified moving forward. Having such a system digitally presents major benefits as the information is more accurate, secure and accessible. Portsmouth Hospitals NHS Trust in the United Kingdom provides an example of how effective inventory management can lead to higher levels of productivity[**24**]. The Trust faced challenges of an increased wastage of resources, inconsistent levels of inventory and incorrectly recording inventory. By introducing a barcode system to uniquely identify inventory they were able to more intuitively and accurately record inventory with stock being reduced by 20% and wasted resources reduced to less than 1% of all resources. More importantly, they now had access to accurate data which could be used to identify more problems over time and promoted higher levels of productivity with the same or fewer levels of resources. An interview with a BMET from Nelson Hospital in New Zealand said that they used Microsoft Access to collate inventory. The BMET described this system as "not user friendly" and "difficult to manage assets". This illustrates the success of an ERP system relies on tailored user interfaces for specific hospital systems. Fishing ERP system has been designed with the hospital staff at the centre of the solution.

## E.1 Stre@mline Case study

Stre@mline is a software solution implemented in South Western Uganda designed to tackle the issue of digitising Health Records in a low-resource setting. It shares many similarities with Fishing in that it is attempting to digitise analogue processes in hospitals in the developing world. Stre@mline provides a means of medication inventory management and patient data management completely offline. Stre@mline also has local technical support available and is economically sustainable without funding from international donors. Stre@mline is currently used by over 60,000 patients at 2 hospitals, with plans to expand across Uganda.[17]

The following table shows the issues addressed by Stre@mline and Fishing in implementing a Health Technology.

| | Stre@mline | Fishing |
|---|---|---|
| Purpose | To deliver a digital means of medication and patient data inventory management, upon other key services such as payroll information. | To deliver a tele-education in regardsto the correct use and maintenance of medical devices. Improve communication channels within and between hospitals. Provide a digital means of medical device inventory management. |
| User-Engagement | Mandated computer workshops for all employees across all departments. | Gamification approach with captivating rewards systems to encourage health care workers to consistently use app. Built on top of a social media aspect which incorporates the use of a feed and chat functionality increasing engagement. This will be supported via hospital workshops. |
| New delivery of existing services | Use of database software to record patient journey data, transitioning from paper to digital systems. | Delivers an interactive approach to educating health care workers about how to correctly use and maintain medical devices. This is done through learning modules and quizzes. Introduction of database software to store E-Learning information and record medical device inventory. |
| Issue of Telecommunications | Uses Ethernet to connect computers in through LAN configuration, allowing the software to work offline. | Uses smartphones in an offline -online configuration to minimise dependence on external infrastructure |
| Issue of Power | Computers are powered by Renewable Energy, and have a back power supply. | Most devices are mobile phones and not affected by external power supply. Only the administrator's computer is, however, UPSs and cloud storage will ensure all data is backed up. |

# Appendix F Fishing's Underlying Features and Technology

Fishing will have three applications that will be used by each of their respective counterparts. The table below shows how each user specific application operates.

| Health Care Workers (Doctors, Nurses etc) | Biomedical Engineer (BMET) | Hospital Administrator |
|---|---|---|
| Purpose | | |
| Increase medical device understanding in order to reduce issues of quick equipment breakdown and promote long term equipment use. Instills accountability into health care workers. | Provide an easier method to monitor inventory over time. This will allow BMETs to better understand why equipment is breaking and move them away from an ad hoc approach of simply repairing equipment to ensuring that equipment is maintained in such a way that promotes long term functionality. | Provide hospital administrators with a clearer view of their hospitals capabilities and resources. This will allow them to manage resources more efficiently and thereby increase productivity. Communicating with other hospitals and agencies is an important part of managing a hospital and will provide a means of doing so. Furthermore, this will open up channels for hospital administrators to get resources such as manuals and training material from medical device providers. |

| Health Care Workers (Doctors, Nurses etc) | Biomedical Engineer (BMET) | Hospital Administrator |
|---|---|---|
| Features | | |
| Mobile Application | Mobile Application | Desktop Application |
| E-Learning<br><br>Access to E-Learning Library. Learning modules that are gamified. Staff are rewarded for completing with their modules virtual currency and can customize their profile more by using their virtual currency.<br><br>Local Communication<br><br>Feed showing report breakdowns in real time. Access to new training modules, news about new improvements to hospital and other hospitals. Messages can be relayed from other organisations via administrator.Staff can also post their E-Learning progress here.<br><br>Reporting/ticketing<br><br>SystemReporting system which allows hospital staff to raise tickets about broken equipment, making repair equipment much easier. This will be relayed to the BMET and Hospital Administrator. | Local Communication<br><br>BMET will also have access to the same social network feed as Health Care workers. They will allow them to see the progress of the hospital, as will all other users.<br><br>Reporting/ticketing System<br><br>BMET will also have see the reporting system which will queue in tickets and resolve tickets as he or she attends to the problem.<br><br>Inventory Management<br><br>BMET will have access to his own inventory management interface that will allow him to record inventory using QR codes. This will be relayed back to the Hospital Administrator via the app. | Local Communication<br>Hospital Administrators will have access to a Desktop Application that will house the social feed element. They will also be able to communicate to other app users.<br><br>Analytics<br><br>Administrators will have access to an analytics dashboard that will be used to monitor E-Learning progress and inventory management. This will give them a comprehensive view of their hospital's operations and allow them to allocate resources more efficiently within their hospital.<br><br>Communication to third parties<br><br>Furthermore, hospital administrators will be able to connect other outside organisations via the internet. This will allow them to better communicate with outside agencies to reduce problems that may exist across many hospitals. |

## F.1 Comparison between the 3 network technologies

| | 3G/4G Cellular Communications | P2P Mesh Network | Wireless Local Area Network (W-LAN) |
|---|---|---|---|
| Description | Cellular communications are provided via cell towers that are installed by local Telecom Providers. | Peer to Peer (P2P) is a way of connecting users directly with each other without a central server | Wireless LAN is a short range wireless connection between devices. |
| Use of technology in a hospital environment | Hospital staff can use their existing cellular connection to access the internet | Health care workers can connect to each other over their phones directly using WiFi Direct and Bluetooth technology. A Large network of phones can thereby be connected to each other without any external hardware. | Staff members can connect to the Wi-Fi connection established by the hospital |
| Advantages | Extremely high range<br><br>Uses existing infrastructure<br><br>Extreme mobility<br><br>Will make Fishing extremely scalable | No additional hardware required<br><br>No single point of failure | Can support offline communications without being connected to the internet<br><br>Users will always be connected<br><br>More control over users in network |
| Disadvantages | Data charges can be expensive<br><br>Requires a sim card and mobile data | Limited range<br><br>No control over users in the network<br><br>High level of complexity just for offline communication<br><br>Software Development Kits for mesh network technologies are expensive | High initial capital cost<br><br>Requires a constant power source to operate |

Table 1: Comparison between different network technologies that could be selected during phase two

Our survey results from Appendix B shows that there is significant smartphone usage across Entebbe Hospital. This suggests that most users do have a mobile cellular subscription. Data from the world bank also shows a sharp increase in mobile cellular subscriptions (in East Africa), indicating that mobile communications is much more common and will increase further into the future[24]. Relying on existing cellular networks will allow for an extremely scalable implementation of Fishing, as most users will be able to view data and communicate over the internet, reducing the need for any additional hardware or software.

P2P Mesh networking relies on building software that allows phones to talk via their BlueTooth and WiFi antenna. This approach is quite novel, however, presents quite a few challenges. The network is extremely dynamic and constantly needs to be learning about each user on the network to create the most optimised network. Furthermore, the Fishing app will need to be designed in a way that allows information to be cached on each device as users interacting with each other will be using the network of phones to relay messages across rather than a central server.

Installing a wireless local area network could be another approach if hospitals are on board. This would involve designing a network and building it for them if they do not already have WiFi. This approach would be more expensive initially but does present major benefits moving forward, with the ability to introduce more information technology-based solutions that help maximise operational efficiency. Outreach engineers were able to build a WiFi network for the University of Ghana using access points that cost US$80 each[25]. This example is a cost-effective approach of installing such a system in the developing world.

Overall each system presents certain advantages and disadvantages and a final solution can only be implemented once more data is gathered surrounding the situation of internet accessibility in target hospitals.

Regardless of what solution is implemented, Fishing will always maintain a combination of offline and online capability as previously mentioned. E-Learning documentation will come pre-loaded with the app and users will be prompted to update the app whenever they are connected to the internet. Fishing will also provide the BMET with access to the internet if they are not able to arrange this, but at an additional cost. These features will ensure that Fishing aims to be extremely scalable and accessible as an informational and productivity tool regardless of the surrounding environment.

# Appendix G Figures

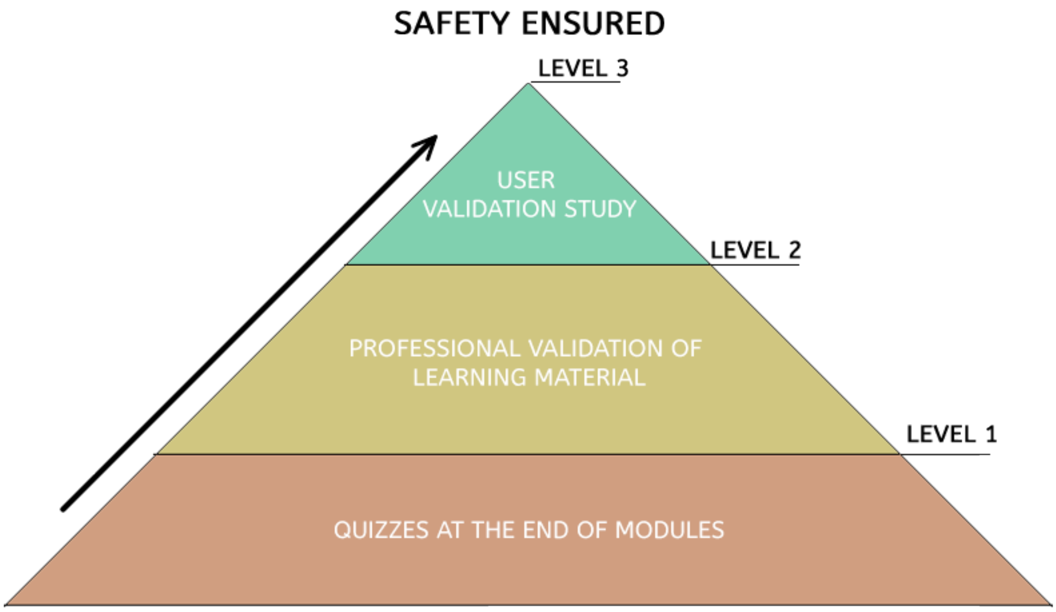



Figure 22: Safety plan

### G.1 User scenario - healthcare worker perspective

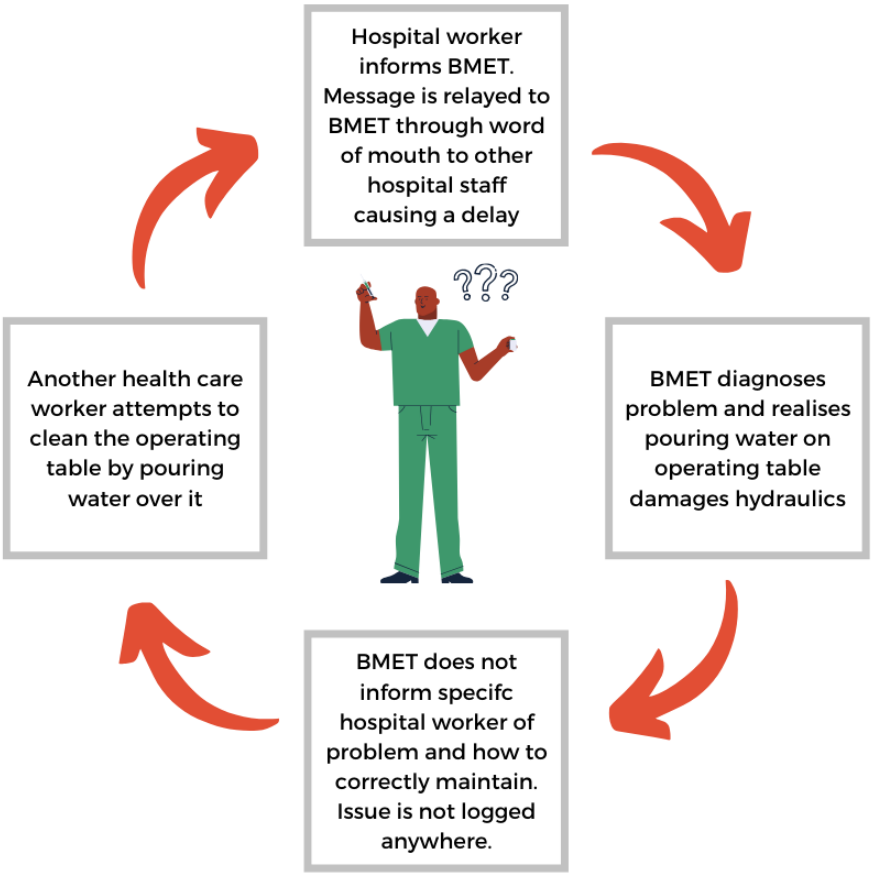



Figure 23: Existing method for reporting device failure

## G.2 User scenario - healthcare worker perspective

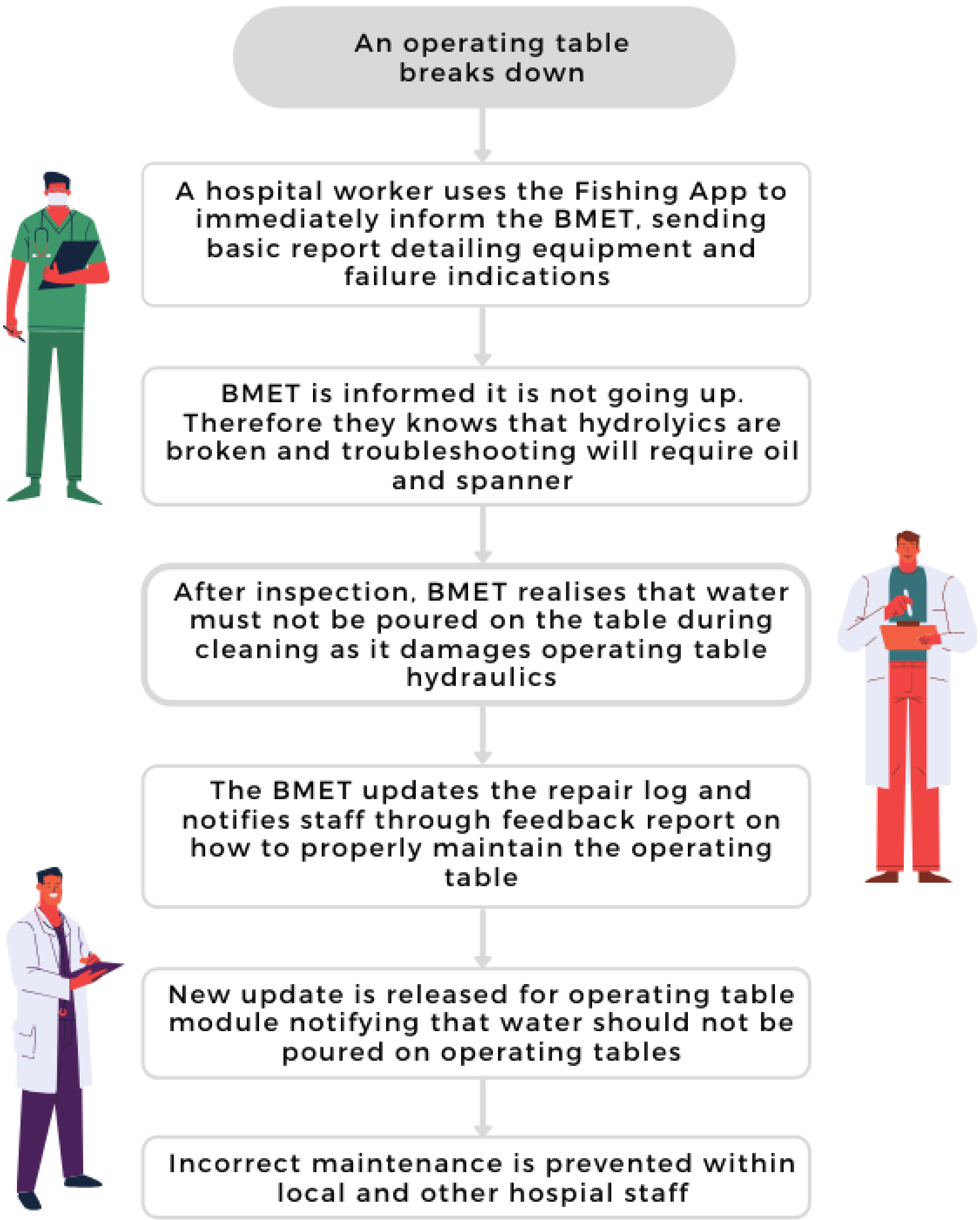



Figure 24: Using Fishing for reporting device failure

## G.3 User scenario - BMET perspective

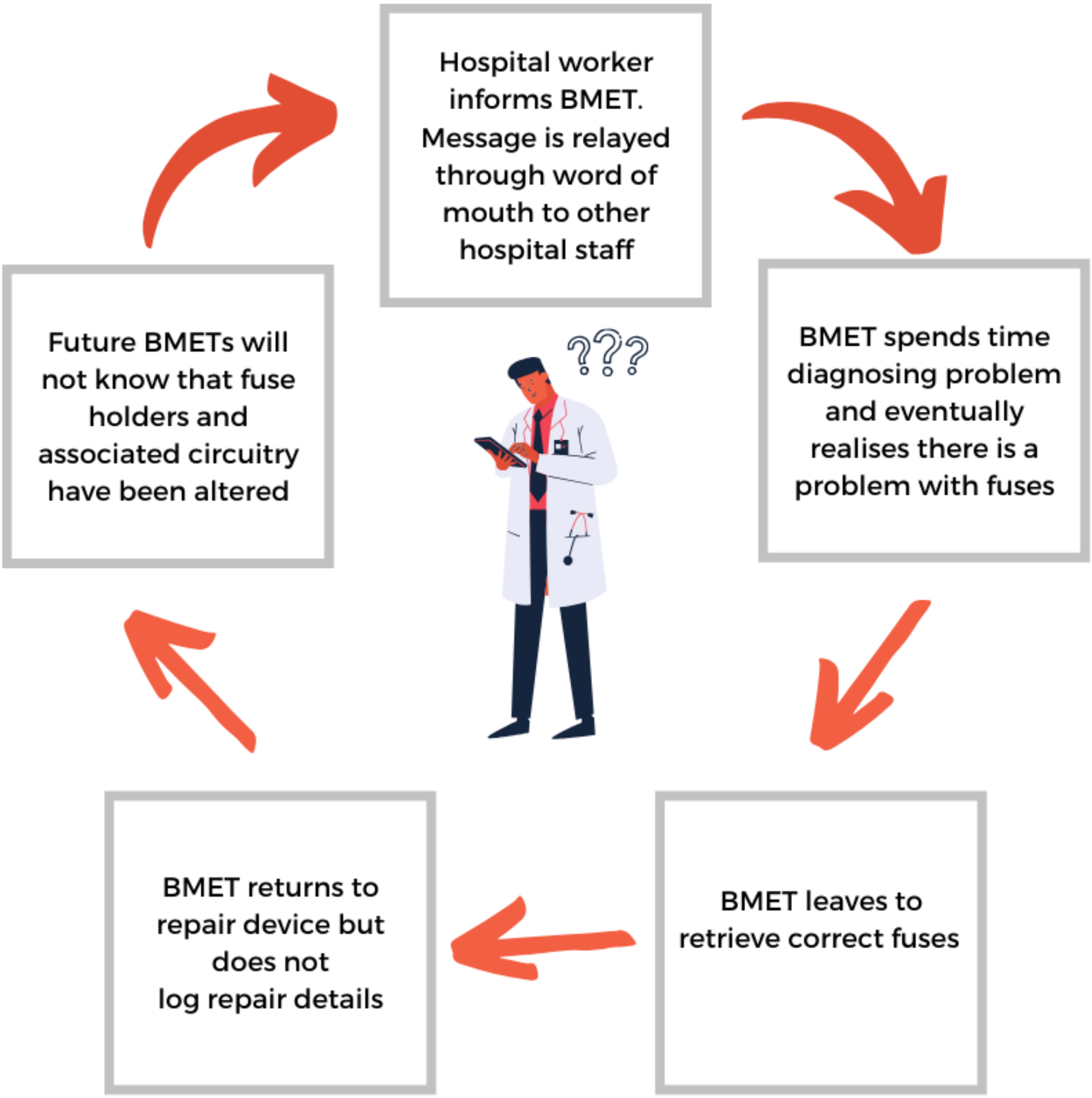



Figure 25: Existing method for reporting device failure

## G.4 User scenario - BMET perspective

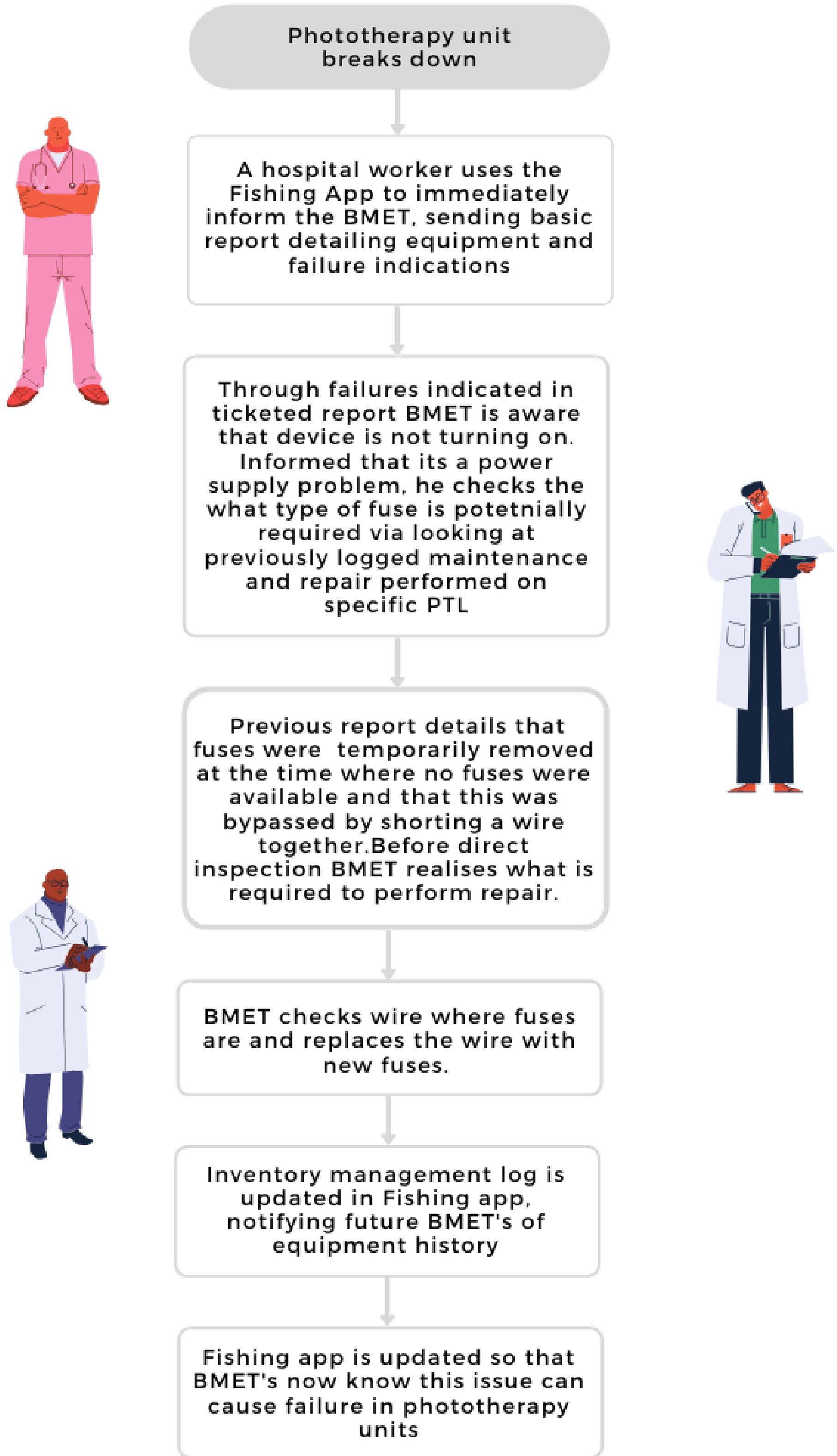



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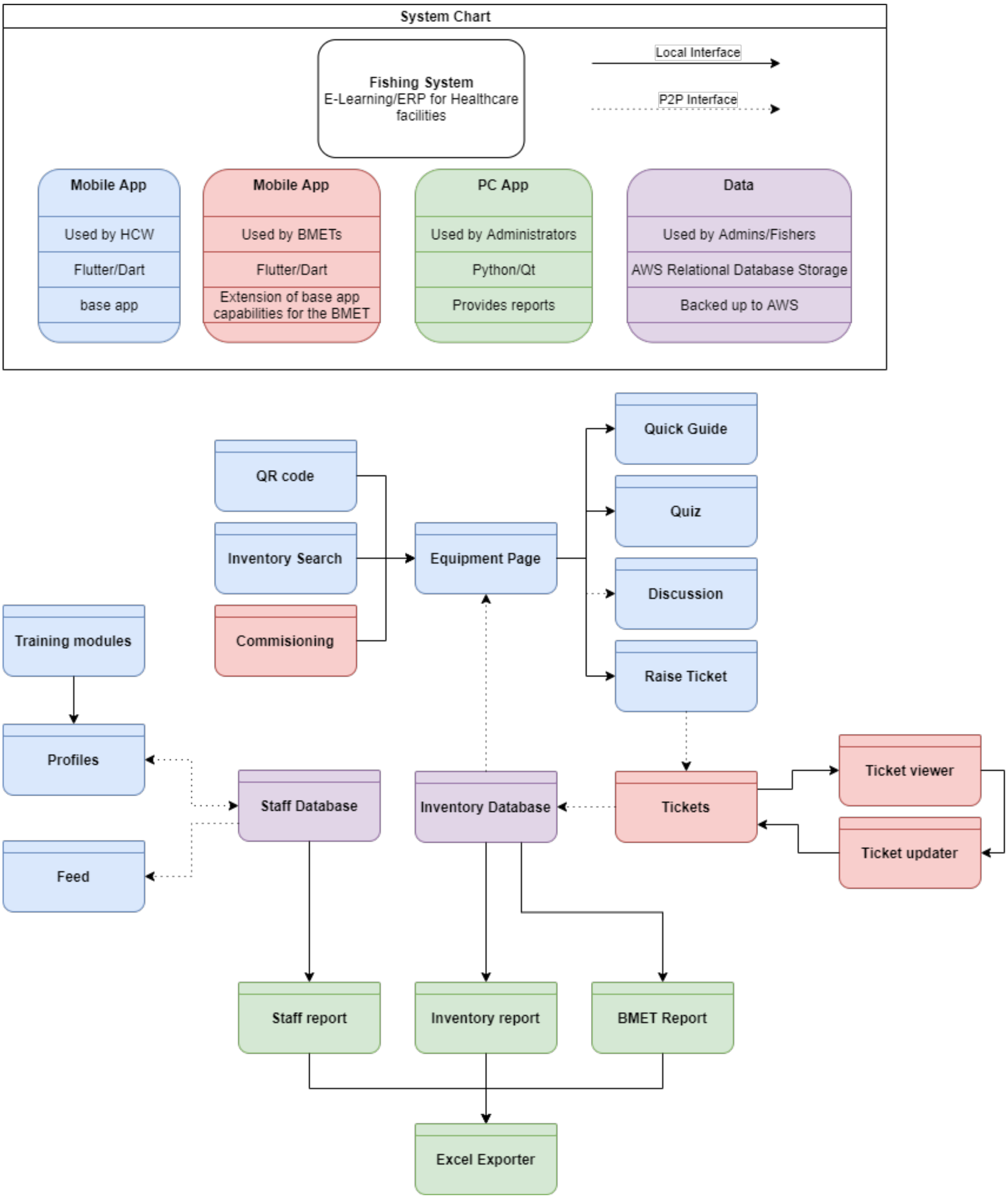
Figure 26: Using Fishing for reporting device failure

# Appendix H Desired Outcome, if Using Mesh Technology



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