INNOVATION DURING A PANDEMIC:
COVID BUDDY

SINGAPORE BIODESIGN

CASE STUDY SERIES

AUTHOR

Dr Scott Wong

DR SCOTT WONG is an internal medicine resident at NUHS, and was previously a Singapore-Stanford Biodesign Innovation Fellow in 2018. He has a passion for digital health, with a vision of enabling healthcare for a wider population through new mobile technologies and data science. He has previously worked in the Ministry of Health in a regulatory role for digital health and telemedicine, and has also worked as a Senior Data Analyst in the Ministry of Health Office for Healthcare Transformation, focusing on home based blood pressure monitoring and myocardial infarction management.

Aside from his clinical duties, he is currently running a startup called Healthpixel, which aims to automate production of medical applications and web applications that are scalable for the masses. The startup has been able to deploy applications in less than a week during the COVID pandemic, and has reach 1.5 million users in a span of 4 months.

INNOVATION DURING A PANDEMIC (A NEEDS-DRIVEN APPROACH)

The SARS-CoV-2 novel coronavirus (COVID-19) outbreak paralysed the world in 2020, with 211 million confirmed cases and 4.4 million deaths as of 24th August 2021 (1). This global pandemic had caused crippling lockdowns, severe economic disruption and overwhelmed healthcare systems.

Image courtesy of Ng Teng Fong General Hospital

Singapore was not spared, with the COVID-19 outbreak being concentrated in migrant worker dormitories in 2020. Exactly 1 year ago on 27 August 2020, there were 56,484 people infected cummlatively, with an overwhelming 94.7% (i.e., 53,466 infections) involving migrant workers residing in dormitories (2). Biodesign alumni in Singapore and across the world stepped up during this crisis to find ways to innovate and deliver a positive impact.

In this case study, Dr Scott Wong (SSB Innovation Fellow, 2018) shares his experience on the frontlines of the medical response and his timely innovation - COVID Buddy. In summary, COVID Buddy is a Progressive Web Application (PWA) that is able to record medical histories, and explain test results and prescription medications to suspected COVID-19 patients. It is deployable even when there is poor or limited Internet connectivity. Its carefully needs-driven design caters especially to the migrant population who speak a different language and may be illiterate.

Frontline Experience

OUTBREAK IN SINGAPORE'S MIGRANT WORKERS' DORMITORIES

"Drop everything and come to the COVID wards NOW!"

This was the call I received in mid-April 2020, when Singapore experienced a surge of COVID infections in the migrant worker dormitories (3). The total foreign workforce (excluding migrant domestic workers) was 984,000, and around 323,000 migrant workers or 33% of this workforce were living in such dormitories (4; 5). Significantly, around 311,000 workers were from the construction, marine shipyard and process (CMP) industries (4). These industries employed predominantly male migrant workers, hailing from countries such as Bangladesh, India and China. According to Singapore law, these workers must be housed in proper accommodation. The close living quarters, shared communal spaces and high transmissibility of COVID-19 led to a rapid outbreak in these dormitories in April 2020 (5).

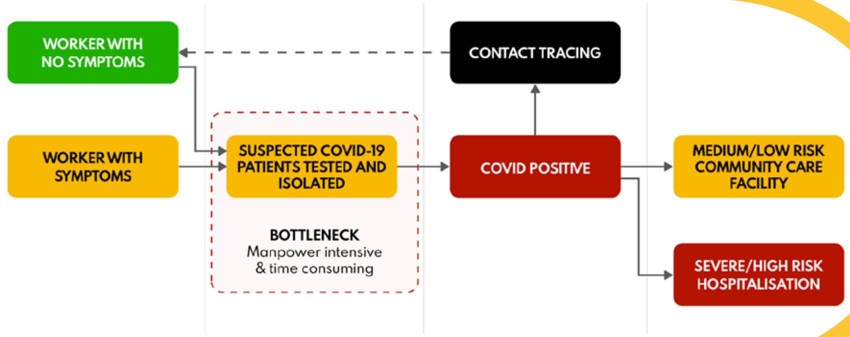

FIGURE 1: Overview of Patient Flow for Worker with Suspected COVID in April 2020

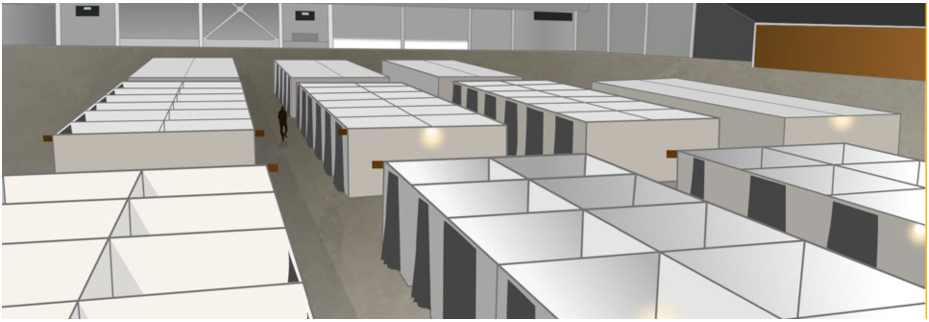

FIGURE 2: Community Care Facility, Expo

To contain the outbreak at the dormitories, the Singapore Inter-Agency Taskforce created a medical support plan on 14 April 2020. **(Figure 1)** This involved setting up medical posts at all 43 large purpose-built dormitories. This enabled early care to be provided, and facilitated early identification, contact tracing and isolation of COVID-19 cases (6). Patients who showed clinical signs of being unwell, or were of older age and/or had existing medical conditions, would be sent to the hospital emergency department. Where necessary, they may be admitted for evaluation and closer monitoring. If not, patients would be sent to a community care facility (CCF) where they would be isolated and receive minimal intervention until they were non-infectious. **(Figure 2)**

As a medical doctor at the frontlines from April 2020 to early August 2020, I had the opportunity to observe the full journey of COVID-positive migrant workers. Initially, I was assigned to the dormitories. Subsequently, I was rotated to the emergency department and wards in an acute hospital; and finally, to the CCF. Throughout the three-and-a-half month period, I was able to witness the unique challenges on the ground and identify critical needs during those adverse circumstances.

Identifying Needs on the Ground

MEDICAL RESPONSE SET-UP IN NON-IDEAL CONDITIONS

At the dormitories, medical posts were set up rapidly in a matter of hours or days. A number of issues became most apparent. A medical post would be manned by a team of one to three doctors, and at least three nurses. Depending on the population of the dormitory, there might also be support staff such as swab teams. (7) Medical teams had to minimise the risk of COVID infections at the medical posts, maintain appropriate safe distancing of 1m to 2m between all patients and staff, and ensure adequate ventilation. This meant that teams had to work around space constraints. Teams also set up medical posts in temporary areas and tentages that were open-air. Many dormitories also suffered from a lack of reliable Wi-Fi or Internet connection. As such, it was difficult to set up a mobile Electronic Medical Records (EMR) systems. Poor Internet connection also meant that patients experienced difficulties in

FIGURE 3: Triage in a Dormitory Setting (Credits to NTFGH)

communicating with their families back home or with medical personnel. As a result, mobile hot-spots and mobile power sources needed to be set up as well. (8)

Given time constraints and the challenges that we were facing, there was little time to set up fully functioning EMR systems. Notwithstanding, we conducted most consultations with pen and paper, and transcribed patients' information subsequently into an EMR system. This time-consuming and resource intensive process was amplified by the heavy workload and rapid pace of the pandemic, where hundreds of patients were triaged daily at its peak **(Figure 3 and 4)**. Whilst managing the huge population to triage, we also had to be very mindful not to be in close contact with patients for too long.

LANGUAGE BARRIERS

As a majority of the migrant workers were from Bangladesh, India and China, medical history taking was often hampered by language barriers. (9) A medical consult could take more than five minutes for the medical personnel to clarify whether a patient had symptoms (e.g., fever, cough or cold), and how long the patient had the symptoms for.

It was also previously noted in a study, where Ang *et al*. found that Bangladeshi workers who spoke Bengali as a native language, faced higher language barriers (compared to Indian and Chinese workers) when seeking medical treatment in Singapore. Unlike Mandarin and Tamil, Bengali is not an official language of Singapore, making it difficult to find a translator.

Local healthcare professionals are also more fluent in English. Thus, it was difficult to obtain accurate histories from the migrant workers or deliver clear information to them within the short consultation time. This sentiment was echoed in a survey of 427 doctors in Singapore by Ang Jia Wei *et al*., which showed that 394 (92.3%) of doctors perceived language and culture to be significant healthcare barriers for migrant workers (10).

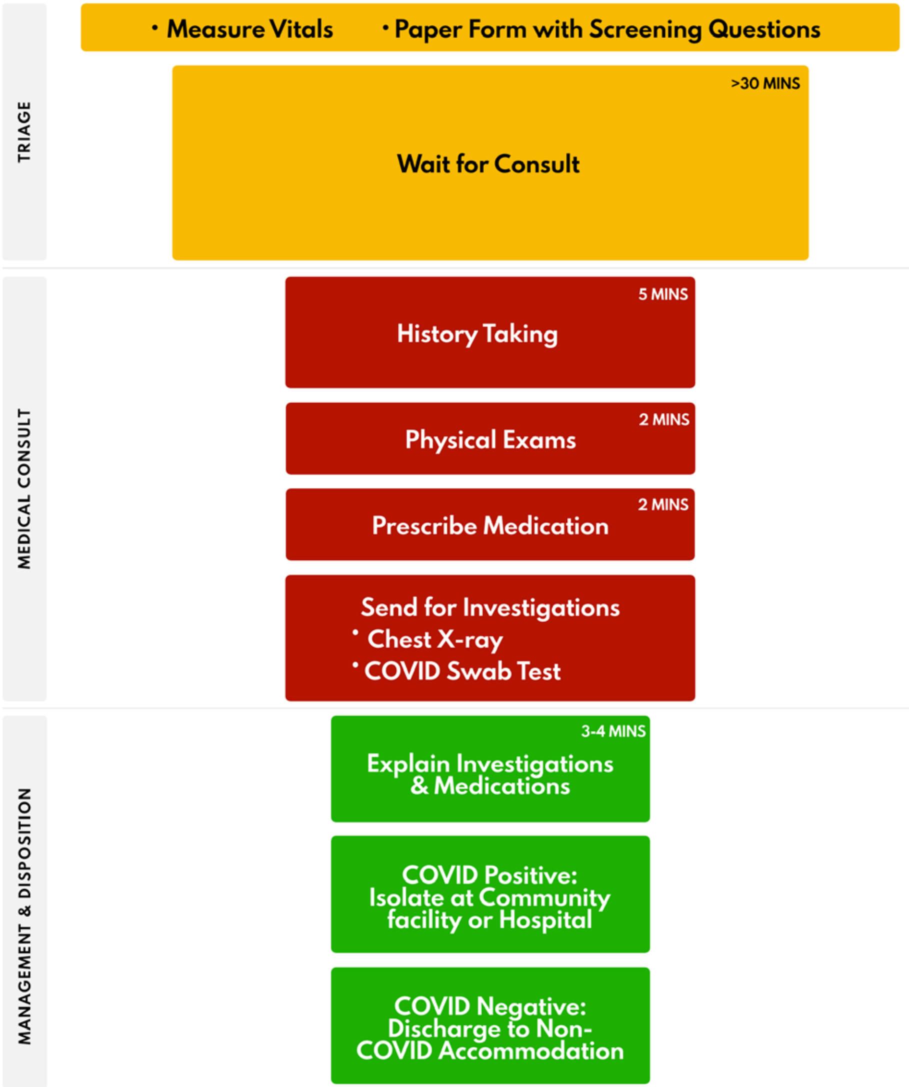

FIGURE 4:. Existing Triage Process

LOW EDUCATION AND LITERACY BARRIERS

We also observed that 20% - 25% of migrant workers had trouble reading medical information written in their native language. This meant that using text-based triage forms was difficult for one in four patients. It was even more difficult for patients to read medication labels when prescribed medication.

While no explicit data sets were found regarding literacy rates amongst migrant workers in Singapore, we note that the average literacy rate of males aged 15 years and older was 76.7% in Bangladesh and 82.4% in India in 2018 (11; 12).

In a Singaporean study of 433 migrant workers in subsidised clinics and a foreign worker dormitory, 49 (11%) had a primary school education or less, 262 (61%) completed secondary education, and 122 (28%) completed post-secondary education. This meant that medical information needed to be simplified if migrant workers were required to consume this information on their own.

Selecting the Need FAST

Given the circumstances on the ground and characteristics of the migrant worker population, we quickly established that medical professionals needed **a way to accurately obtain information on symptoms, and explain results and medications to large groups of migrant workers, in an environment with limited Internet connectivity and low electricity, to reduce consult time and infection risk to medical staff, while reducing patient misinformation and anxiety.**

Keeping in mind the need for speed and practicality, I focussed on three key strategies that would enable me to implement a solution swiftly.

1. The need must have a potential digital solution.

   With personal experience in software and digital health, I could build a minimum viable product quickly. In addition, with a digital solution, scaling and implementation would not be hampered by logistical and physical distribution problems. These problems might result from supply chain disruptions due to restrictions on global travel and shipping during the pandemic.

   This meant that needs involving developing personal protective equipment or ventilators had to be deprioritised. My inclination then was geared towards needs dealing with mass contact tracing or community detection of acute respiratory distress.

2. The need must retain moderate relevance after 6 - 12 months

   The need to remain relevant was to account for potential changes in workflows and advisories as the situation progresses. This provided an insight that a bottom-up approach to data collection from the ground was most suitable in the chaos of a pandemic. Official data reporting and collection, on the other hand, would more likely be disrupted. Therefore, on-the-ground ethnographical data collection would be more relevant for predicting potential future needs. For example, the team hypothesised that vaccination of patients against influenza and COVID-19 would be an important pandemic-mitigation community prevention need in the next phase of tackling the pandemic. For such an initiative, there would remain a need to accurately obtain histories and explain vaccinations en masse to the migrant worker population. To remain relevant, COVID Buddy is currently in the process of evolving to Vaccine Buddy to meet changing needs and communicate healthcare information to the migrant population.

3. The need can be constantly validated with stakeholders

   The ability to get good stakeholder alignment and implementation support was critical, as stakeholders would be under great time and resource pressure to react to the COVID-19 pandemic. Doing validation from the ground up was an opportunity to uncover various need agendas of stakeholders and obtain support to implement a solution with existing staff on the ground. For example, I realised early on that several prominent stakeholders were already individually focussed on vital signs monitoring in the dormitories. This meant that instead of focussing on vital signs monitoring, a possible solution would be to integrate such existing monitoring solutions. Similarly, multiple stakeholders showed concern for data privacy and storage of patient details on the cloud. This influenced our decision to have all data stored on the patient's phone with no central data repository.

Needs Criteria – Focus on Development and Execution

After validating the need, I prioritised implementation and scalability to cater to the mass migrant worker population. The needs criteria as of 26 April 2020 were as follows:

1. Ability to obtain reliable history and demographics with patient contact of less than one minute, while maintaining the recommended safe distance of at least one metre away from patient;
2. Deployable to 20,000 dormitory workers and healthcare workflows in less than 48 hours;
3. Usable in places with limited Internet connectivity; and
4. Compliant with Singapore's Personal Data Protection Act (PDPA) and the US Health Insurance Portability and Accountability Act of 1996 (HIPAA) to maintain patient privacy.

Criterion 1 was the only medical criteria. Based on observations, medical staff were spending more than five minutes in close contact (and at less than one metre) with COVID-positive patients. Hence, it is important to reduce time and ensure that a distance of at least one metre can be maintained between the patient and staff to reduce overall risk. This was particularly pressing in settings where personal protective equipment was not readily available.

Criteria 2, 3 and 4 were focussed on addressing key implementation challenges in the local context. For instance, most migrant workers would continue to be in a dormitory or isolation facility with issues such as poor Internet connectivity. This was noted early in the development process, where I conducted 170 patient interviews with the alpha prototype. Testing was carried out in the dormitories and isolation areas in hospital basements, where Internet connectivity was very limited. Some patients were even sent to cruise ships.

The last criterion refers to the Singapore PDPA, which seeks to ensure privacy of data collected. This criterion was identified as a key risk for mass implementation in Singapore and abroad, and influenced further prototyping and invention.

Inventing to Implement – Launching a Progressive Web Application

Early on, we noticed that most migrant workers have a smart phone, especially for entertainment and communications purposes, while placed under isolation (8). It was also observed that more than 90% of the migrant workers possessed an Android phone, which cost around SGD$150 to SGD$250. However, the phones might be several years old and operating systems were often not updated, with some phones running Android Marshmallow (Version 6). In order to meet criteria 2 and 3 above, a decision was made to build a PWA rather than a native app. A PWA is a website that downloads itself onto the user's phone for offline usage and has app-like capabilities that could be launched on the stock Samsung or Google Chrome internet browsers. A comparison of PWAs vs Native apps can be seen in **Table 1**.

The build process started with three weeks of rapid prototyping in May 2020. Adobe XD was used, with 170 patient inputs and 11 iterations to ensure that the product could be implemented in the local context and integrated into the workflow. Once the user interface and functionality were optimised, we transitioned to testing a preliminary version of the PWA in the

PROGRESSIVE WEB APP		NATIVE APP
USABLE ACROSS PLATFORMS	PLATFORM	SPECIFIC TO PLATFORM
LOW PRODUCTION COST	COST	HIGH PRODUCTION COST
NO INSTALLATION	INSTALLATION	HIGH PRODUCTION COST
SMALLER FILE SIZE & DATA	SIZE	LARGER FILE SIZE
USABLE OFFLINE, EASY UPDATES	UPDATES	REQUIRES REGULAR UPDATES
SIMPLE FEATURES	FEATURES	HIGHER PERFORMANCE

TABLE 1: Comparison between PWA and Native Applications for Use in the COVID-19 Pandemic

temporary medical areas and the workers' dormitories. The priority was to make the PWA simple and durable, where it could be deployed rapidly in over 80% of the patient's phones in the dormitories or isolation facilities. The final product at covidbuddysg.com was ready for launch in the 3rd week of June, and was formally deployed at a CCF in Singapore at the start of July 2020. The timeline from production to deployment can be seen in **Table 2**.

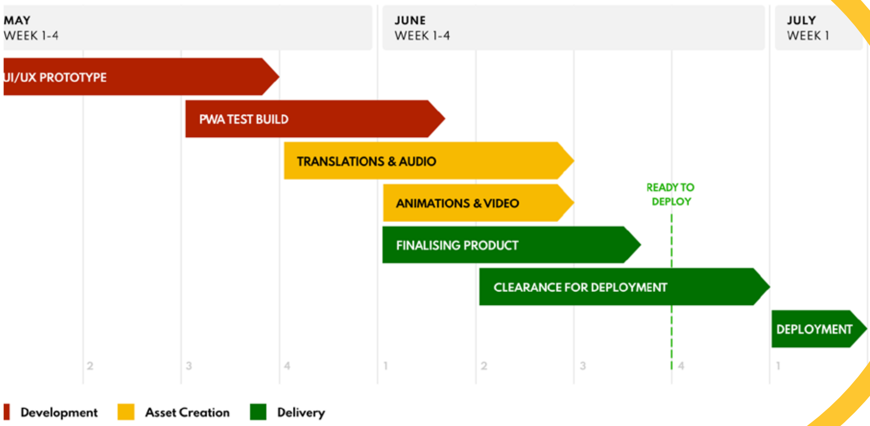

TABLE 2: COVID Buddy PWA's Timeline (from production to deployment at a CCF in Singapore)

Main Features of COVID Buddy

COVID Buddy uses audio, visual and text cues to obtain symptoms from illiterate patients through a series of questions. Symptoms of COVID-19, such as cough, sore throat and diarrhoea were first illustrated by hand during development. They were then shown to the migrant workers. Only pictures where at least 90% of the workers could identify the symptom correctly were used.

In addition, only one symptom is shown on each page. The patient will be asked if he has such a symptom in text and audio. The text and audio are available in five main languages – Bengali, Tamil, Thai, English and Mandarin. To respond, patients will need to select 'Yes' or 'No' (in their own native language) contained in green and red buttons **(Figure 5)**.

After a patient completes the symptom checker, a button labelled "QR & results" will be available. This displays the patient's responses in English, with information encrypted on a QR code, which can be scanned into an electronic records system or phone. This enables medical personnel to quickly and accurately look at the results on the patient's phone while maintaining a distance of more than 1m from the patient, thereby reducing infection risks.

COVID Buddy can display investigation results, disposition for patients, and also explain the indication and use of prescribed medications. If a patient has any positive test results, the medical personnel can go to a password-protected page and select relevant results to explain to the patient. The results are then displayed in both text and audio for patients in their selected language **(Figure 6)**. Patients can also send their results via messaging apps to their loved ones to keep them informed.

In addition, the results are linked to a QR code which enables a medical personnel to scan the information at a safe distance (of at least one metre from the patient's mobile phone). The results can also be scanned directly into an EMR. For completeness, the QR code provides a timestamp of when a diagnosis of COVID was made and medications prescribed.

As common symptomatic medications are often prescribed to patients, COVID Buddy was built with this in mind. The app automatically displays pictures of the medications, with clear instructions in both text and audio (in the patient's preferred language) on how to consume the medications. This can reduce nurses' and pharmacists' workload in explaining the medications to the patients, and overcome language barriers.

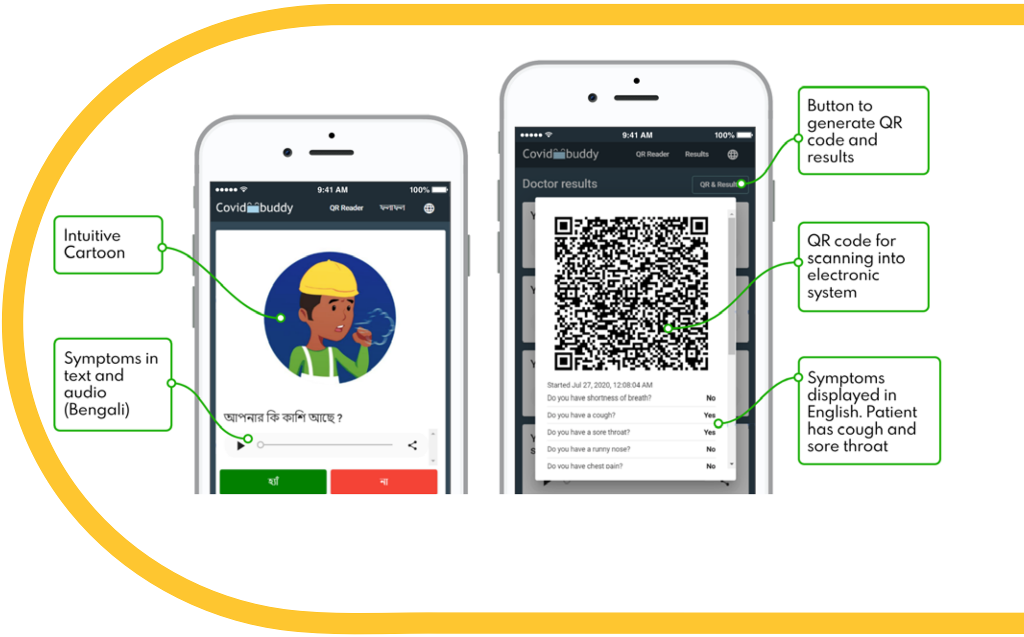

FIGURE 5: User to respond if he has cough symptom (Left), QR code and results after user responds (Right)

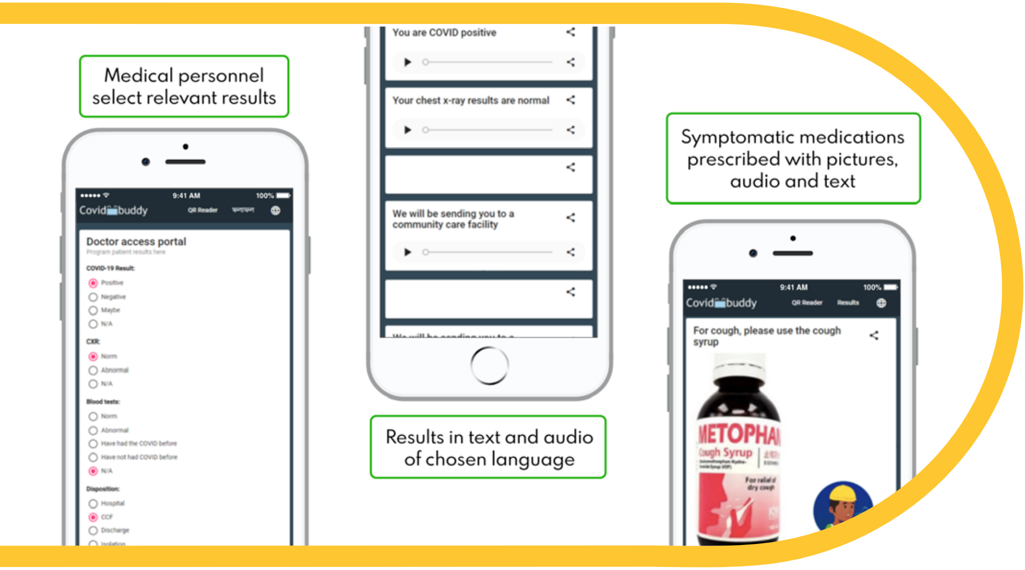

FIGURE 6: Screenshots of COVID BUDDY app. From left: (1) Medical personnel selects results. (2) Patient views results. (3) Patient views explanation and consumption of prescribed medications.

DEPLOYMENT ON THE GROUND

Since July 2020, COVID Buddy has been deployed at a CCF in Singapore housing COVID-positive migrant workers. When patients are admitted to the facility, they will be issued a Wi-Fi password and directed to covidbuddysg.com, which takes them to the PWA. Nurses then take the patients' vital signs. Patients are able to use the COVID Buddy app before they are seen by a medical doctor.

The usage of the application was monitored by mixpanel.com, which is a third-party and blinded software that can analyse how a migrant worker uses COVID Buddy. In the first 14 days of operations of the facility (3 July 2020 to 17 July 2020), about 453 unique patients (out of 500 total patients) managed to load the web page. Approximately 355 of these patients (78.4%) proceeded to select a language and start the symptom checker. **(Figure 7)** These were our observations on the ground: (A) Slow Wi-Fi connectivity causing the page not to load fully; and (B) Mobile phones with Android OS older than Android Version 7.

Of the 355 patients who selected a language, about 248 patients (70%) managed to complete the symptom checker and reach the results page. For patients who were unable to complete the application, it could be because they were hurried along to see the doctor. For others, they exited the webapp halfway and encountered difficulties when re-entering the app.

This led to an overall conversion rate of around 55% after deployment. Efforts to improve conversion rate are ongoing.

Overall, COVID Buddy was able to achieve the following improvements in the triage process and beyond, as a suspected patient moves through the various stages of care:

- Carry out a comprehensive history of the 10 most common symptoms (fever, diarrhoea, muscle aches, etc.) whilst screening patients for anxiety and worry.
- Shorten doctor consult time per patient from 9 – 11 minutes to 5 – 7 minutes. In other words, screening at a 100-pax scale could result in manpower savings of more than six hours. It could also potentially reduce the need for triage staff. **(Figure 8)**
- Allow healthcare workers to maintain a safe distance of more than one metre from the patient to reduce infectious spread.
- Can be used in places with limited Internet access and low resources.
- Allow doctors, healthcare teams and families quick access to useful information such as review history, acute management, post-discharge care and counselling services, which further amplifies manpower and operational efficiency for all stakeholders.

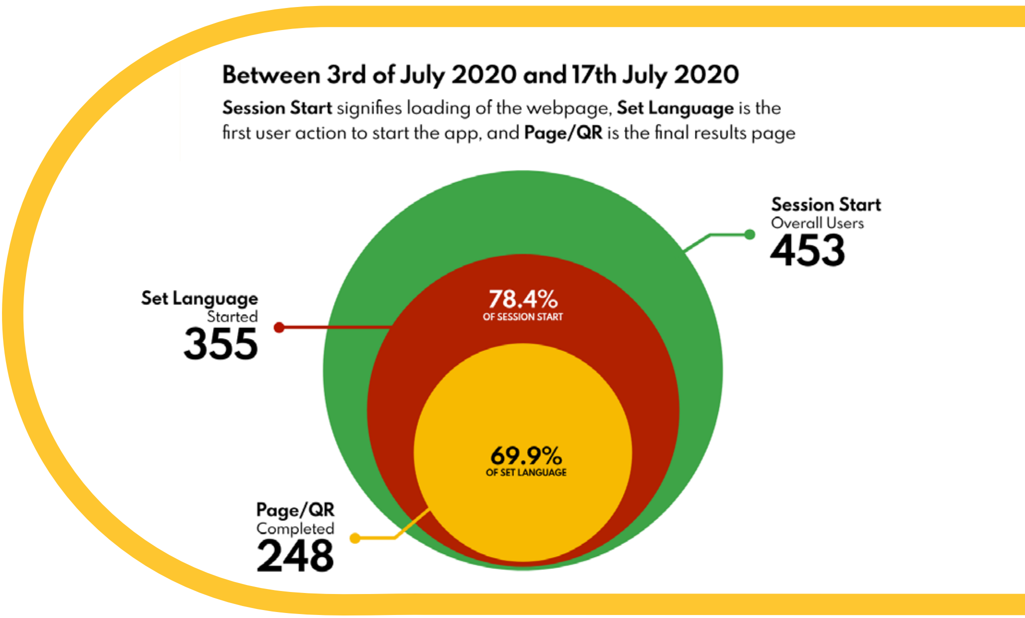

FIGURE 7: Usage statistics on mixpanel for COVID Buddy between 3 and 17 July 2020. Session Start signifies loading of webpage, Set Language is the first user action to start the app, and Page/QR is the final results page.

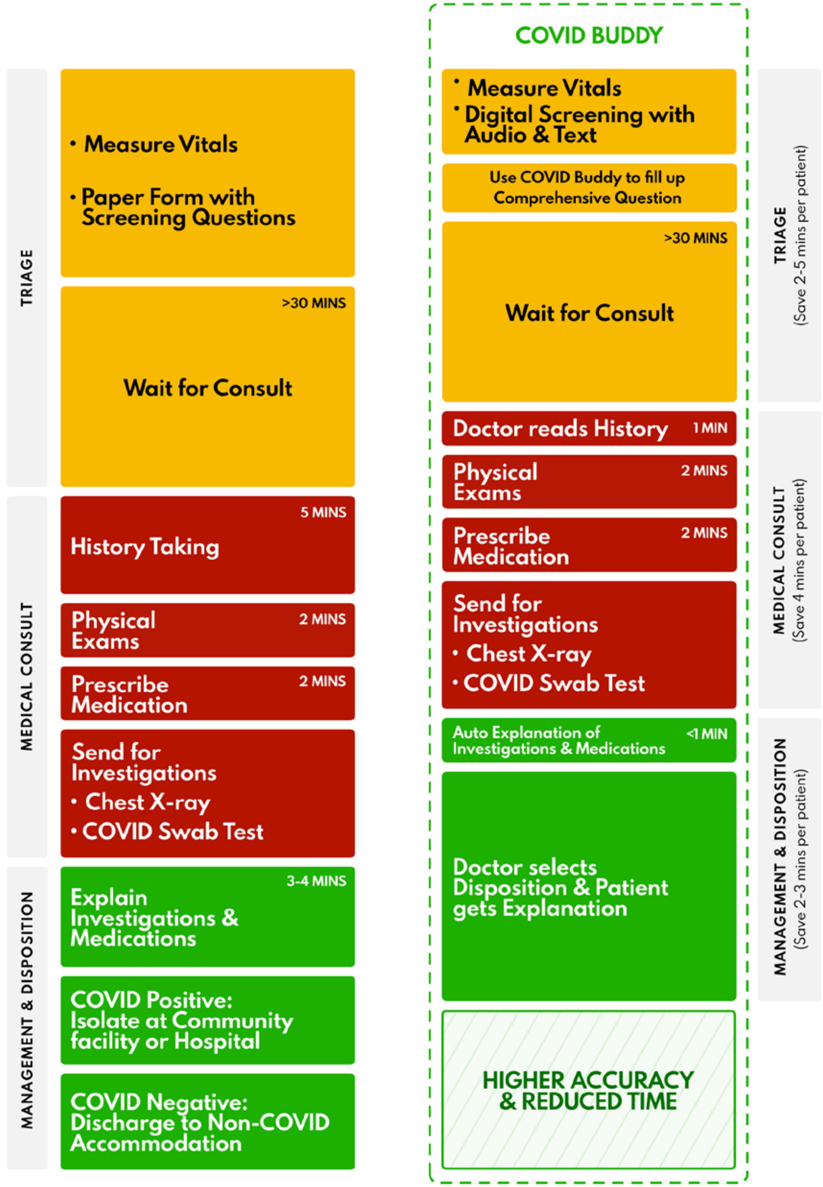

FIGURE 8. Improved Triage and Management Process of Suspected COVID-19 Workers at the Dormitories with Covid Buddy

CONCLUSION

We hope that the insights gleaned in creating the PWA can be used in other regions afflicted by the COVID-19 pandemic. The insights will be especially useful for places where medical consultations have to take place with limited Internet connectivity and low resources. The ability for patients to select their preferred language in the app is particularly useful where there are language and literacy barriers.

We believe that it is imperative that digital tools be built to be scalable and durable, and providing medical value by simply being on the patient's personal mobile device. In addition, COVID Buddy and other PWAs can be deployed in a matter of weeks.

In terms of efficiency, COVID Buddy can reduce the consultation time during a medical consult, while reducing contact time and infection risk to medical professionals.

The project can also be converted to serve other needs, such as screening of psychological distress or explanation of localised treatment protocols. We have made the project open source so that it can be adopted rapidly in any area afflicted by COVID-19. The source code is available at https://github.com/COVID-Buddy/covid-buddy and the web application is available at covidbuddysg.com.

FUTURE DIRECTIONS

Overall, the Biodesign needs-centric approach has enabled me to purposefully identify crucial needs on the ground, despite the frantic pace and lack of information in a pandemic. By constantly, innovating and implementing around the needs, I was able to focus on the essentials and deploy the solution to thousands of patients in less than 10 weeks.

Covid Buddy has now been improved and converted to ART Buddy, which aims to solve real time COVID antigen rapid testing for millions of people in low-resource settings. The fight is not over yet. We hope that a methodical approach, geared towards people's needs, will enable us to rapidly identify and implement solutions for this pandemic and future healthcare situations.

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Dr Mary Kan

Programme Director

Dr Phin Peng Lee

Deputy Programme Director

Ms Fiona Loke

Curriculum Head

Ms Preeti Mohan

Product Development Engineer

Mr Alex Choh

Innovation Training Manager

OTHER CONTRIBUTORS

Mr Gobind Singh

Ms Karen Wong

Mr Arfandi Azzahar

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Modelled after the established Biodesign Programme at Stanford University, Singapore Biodesign is a capability development initiative that aims to train and nurture the next generation of healthtech innovators for Asia.

We are a dedicated talent development and knowledge resource for health technology innovation, riding on the robust biodesign methodology and our wide-ranging regional network to provide an appreciation of healthcare needs through observations from stakeholder perspectives.

MISSION

High-touch development of healthtech talent centered on needs-based approach and quality industry mentoring to accelerate health technology innovation and adoption for Asia's* unmet healthcare needs.

VISION

To be Asia's* leading healthtech talent development and knowledge partner for accelerating health technologies innovation towards commercialization and adoption.

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sbenquiry@hq.a-star.edu.sg
sgbiodesign
sgbiodesign

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