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Using Work System Design, User Stories and Emotional Goal Modeling for an mHealth System

Nik Nailah Binti Abdullah*, John Grundy†, Jennifer McIntosh†, Yen Chia How‡, Sahrin Saharuddin‡,
Koh Keng Tat§, Eng ShinYe§, Angie Julaina Anak Rastom§, Noorma Liyana Othman§
* *School of Information Technology*, *Monash University Malaysia*
nik.nailah@monash.edu
† *Faculty of Information Technology*, *Monash University Australia*
john.grundy@monash.edu, jenny.mcintosh@monash.edu
‡ *Clinical Research Center, Department of Cardiology*, *Hospital Queen Elizabeth II*, Sabah, Malaysia
§ *Heart Failure Clinic*, *Pusat Jantung Sarawak*, Sarawak, Malaysia

***Abstract*—In Malaysia, Heart Failure (HF) is one of the commonest reasons for hospitalization, with a quarter of HF patients readmitted within 30 days from the onset of acute HF. Reducing frequent hospitalization from HF would significantly reduce the burden on the health care system and resources. The opportunity exists to create digital health system to provide continuous patient care after the diagnosis of HF and subsequent discharge from inpatient care to reduce hospital readmission. This paper reports our ongoing project in Malaysia with the Ministry of Health Malaysia cardiac centers to address some of the barriers to continuous care for patients with chronic HF using digital health systems' interventions. We have applied a combination of existing requirements approaches – work system design, User Stories, personas, and emotional goal modeling – for the elicitation, modeling, and analysis of requirements. In this paper we report the results of our research including key contributions, lessons learned and the strengths and limitations of our approaches.**

***Index Terms*—requirements gathering, socio-technical perspectives, human-centric, emotional goal capturing, user story**

I. Introduction

Heart failure (HF) is a condition whereby the heart has a reduced ability to pump an adequate supply of blood to meet the body's needs. Common signs and symptoms of HF are fatigue, dyspnea (shortness of breath), and fluid retention. As HF progresses and the heart weakens, reduced blood flow causes organ function impairment, requiring repeated hospitalization. Since 2014, HF has been defined as a global pandemic, affecting around 26 million people worldwide[1][2]. In Southeast Asia, HF also presents at a younger age (median of 54 years) compared with patients living in the United States of America (median of 75 years), and patients in SEA are more likely to present with more clinical features, incur longer hospital stays, and suffer from higher in-hospital mortality [3]. In Malaysia, HF is a very common cause of hospitalization, comprising 6 to 10 percent of all acute admissions[4].

Frequent hospitalization imposes a high burden on the health care system and resources. Keeping HF patients out of hospital by using patient self-monitoring is a demonstrated method to decrease patient admission[3] and reduce the economic burden on the health system[3]. The European Society of Cardiology guidelines recommend chronic HF patients should self-monitor, identify, and manage their symptoms (including mental health symptoms), adhere to prescribed medication, diet (e.g restricted sodium), and exercise regime[5]–[6].

Digital health-based care delivery provides an opportunity to design and create ways to increase patient self-efficacy and continuous patient care after an initial diagnosis of HF and subsequent discharge from hospital[3]. Digital health care interventions can be used to facilitate self monitoring by helping patients recognize their symptoms and physical signs so that they are more able to self manage their disease as an outpatient [7]. Digital health innovations include e-learning, remote monitoring, and m-health apps [8].

This paper reports the results of our ongoing project in Malaysia with the Ministry of Health Malaysia cardiac centers. We aim to address the barriers to using digital health interventions to improve continuous care for patients with chronic HF. Our objective is to create a machine learning (ML)-based algorithm to predict which patients with HF will have poorer outcomes, and develop a proactive monitoring and intervention system to improve their ongoing care. Our long-term goal is to define a software agent (AI) guided requirements' engineering methodology in the domain of digital health systems for many cardiovascular diseases. In this work we have applied a combination of existing requirements' methodologies including 1) Work System Design (i.e., WSD), [9], 2) User Stories[10], 3) personas [11], and 4) emotional goal modeling [8] to explore the elicitation, modeling, and analysis of requirements. The approaches were chosen for best-fit to our problem domain and applied and improvised iteratively with the healthcare stakeholders directly involved in the clinical management of HF in Malaysia.

The rest of this paper is organized as follows: firstly, an outline of the motivation for the project, followed by a review of related work and existing requirements engineering methodologies, then a description of the requirements engineering approaches we chose, followed by results and evaluation. We conclude the paper with a discussion highlighting lessons learned, strengths, and weaknesses of our work to date.

II. Motivation

Acute HF decompensation (ADHF) is a major contributor to non-communicable disease morbidity in Malaysia. We focus on patients with HF who require cardiac resynchronization therapy (CRT), and they have digital monitoring and intervention with implantable cardiac defibrillator devices (CRT).

Our previous work practice observations and interviews with Malaysian healthcare providers suggest that healthcare providers face two major challenges when implementing technology developed in established markets (i.e., by companies that operate multi-nationally)[12]. Firstly, advanced technology, such as implants, are designed and developed mainly concerning the needs of and data from the patient population in the countries that represent the manufacturer's primary market. However, the patient population in countries in SEA, such as Malaysia, have different needs and patient populations and potentially requiring different cardiac remote monitoring systems. The differences are due to different practices of medicine, hospital processes, policies, roles, guidelines, procedures, including the cultural belief-systems of patients when compared to countries where the primary market is developed. [7].

Often mHealth systems require a configuration that is custom fit to the clinical work system of the hospital (hospital process, policy, etc.). The configuration to fit the total work systems of a hospital can incur high implementation costs when the work systems differ substantially [13]. In the end, the healthcare system loses potential benefits if the technology offered is too costly for the population, if the population cannot access it, or if the efficacy of these high-quality advanced technologies cannot be validated. Therefore, the requirements process must involve local key stakeholders, including clinicians and patients, very early on so that technology "fits" the clinical care and management required. Importantly, the digital health systems should not further burden the clinic workload, as an example, increasing numbers of generated alerts to be "seen" could eventually conflict with seeing the scheduled patient in clinics.

III. Related Work

In the work of [13], the authors suggest that to ensure the value and quality of digital health systems it is essential to explore user-driven requirements from an early stage of system development. Given user-driven requirements will vary across types of digital health solutions based on functionality (diagnostics, monitoring, care coordination, etc.), it is important to objectively evaluate the technical and clinical usability, and cost once requirements have been established [13].

In other related work [7], the authors applied a design thinking approach as a process to genuinely understand client needs and explore the preferred solution within the agile/waterfall spectrum in designing an e-Pharmacy system. The approach involved an observational study at the pharmacy, interviewing stakeholders, and contextualizing the solutions within the pharmacy work setting. The engineers/developers immersed themselves in the problem space to help identify needs and to improve healthcare service processes and practices[7].

At Human-Centered Computing in the Intelligent Systems Division of NASA Ames Research Center (from 1998-2013), computer scientists [9], developed the work system design (WSD) methodology over a decade and applied for workflow operations redesign in developing the metabolic rate advisor (MRA) prototype – a health monitoring system for astronauts [14]. WSD methodology is a socio-technical approach. WSD involves systems thinking when designing and developing software [9], redesigning workflows, resulting in a new WSD model to be simulated to output a series of work system simulation behaviors. The MRA system consists of a personal agent [14] for the astronaut who interacts with his or her life support system, serving as a personal health monitoring and work assistant for astronauts working outside a spacecraft [38, 39]. The system continuously monitors the astronaut's health, life support consumables, and extra-vehicular activity (EVA) plan, and advises the astronaut about the need to drink, eat, slow down, return to the habitat, etc. by continuously predicting the astronaut's metabolic rate based on all health and space-suit sensor data.

An "emotion-oriented" requirements-driven approach [8] looks into the aspect of capturing and modeling emotional goals as part of a socio-technical system, to complement more traditional functional goal and task modeling. Thus, the emotional goals are seen as key socio-technical needs from the system, and are equally as important to capture and analyze for the evaluation of patients' acceptance of the resultant mHealth system.

IV. Choice of Requirements Methodology

To address our project goals we needed to view Digital Health (mHealth) intervention solutions as a system design problem. Thus we choose a more socio-technical and human-centric approach to the adopted requirements methodology. The context of software development for the Digital Health system design required capturing and understanding the following: i) the work practices (i.e., workflow) of the healthcare providers at the H.F. clinic, ii) the healthcare policy, iii) constraints, iv) including patients' needs (i.e. emotions), and evaluation of acceptance (i.e. emotional goals). Specifically, we chose to apply the WSD [9] requirements analysis approach that used work practices analysis for observation to capture workflows, roles, tools, and activities. We applied a combination of User Stories[10], personas[11], and emotional goal modeling [8] to capture detailed information about healthcare stakeholders – clinicians, patients, caregivers – needs, emotional goals, and used these to support evaluation of system acceptance.

A. Stakeholders

The key project stakeholders include the following.

Subject Matter Experts – clinicians and healthcare workers:

- Senior consultant cardiologist specialist in HF, a cardiologist, a medical officer researcher in HF clinic, and a medical officer in HF. Location: a MOH Cardiac center located in the Northern part of Borneo, East Malaysia
- Senior consultant cardiologist specialist in HF, consultant electrophysiologist (EP) cardiologist, a medical officer managing the HF clinic, an HF clinic nurse, an HF research assistant. Location: a MOH cardiac center, Northwest Borneo island, East Malaysia,
- Senior consultant E.P. cardiologist, a medical officer, medical officer research. Location: a MOH cardiac center, Northwestern part of West Malaysia.

The clinician subject matter experts are also end-users of the Digital Health system as they use the final product as part of their remote HF management. This includes other clinical staff in the HF clinic and collaborating primary care centers distributed around the region.

Subject Matter Expert – policy:

- A Ministry of Health medical council board member specializing in endocrinology and evidence-based study for policy translation

End Users – Patients and MOH cardiac center clinicians, and healthcare workers:

- Location: Northern part of Borneo, East Malaysia, the patient population are mainly from Malay, Chinese ethnicity and includes indigenous populations (i.e. Dusun, Murut, Bajau). The languages spoken include: Bahasa Malaysia, English, and indigenous population dialect. Religion: Islam and indigenous belief-systems.
- Location: Northwest Borneo Island, East Malaysia. The patient population is primarily Chinese ethnicity and includes indigenous population (i.e. Kadazan, Dusun, etc). The languages spoken: Mandarin, English and indigenous population dialect. Religion: Islam, Buddhism, Christianity, and indigenous belief-system Location: Hospital
- Northwestern part of West Malaysia, the patient population is primarily Malay ethnicity and includes rural Malay. The languages spoken include Bahasa Malaysia and local dialect. Religion: Islam

The patient population age group that would be the end-user of the Digital Health App are between the ages of 23- 60 years old, determined by the subject matter experts.

Technical Experts as Consultants:

- Computer scientist and cognitive scientist specializing in artificial intelligence (autonomous software agents), Brahms language and workflow agents for knowledge expertise and modeling.
- Machine learning engineer who specializes in non-linear small data machine learning algorithm for human health performance and resilience.
- Mathematician specializing in mathematical theory and engineering applications of non-linear dynamical systems with focus on autonomous and aerospace systems.

The technical experts are not located in Malaysia but are in the United States of America

Core team:

- Requirements engineer academic researcher
- Software engineers academic researchers
- Software engineer third-year Honors students as software developers for developing early proof of concept
- PhD student researching into the development of machine learning early proof of concept

The core team members are located in Malaysia and Australia.

Independent Industry Advisor:

- EP cardiologist in cardiac resynchronization therapy and advanced heart failure therapeutic devices, a specialist with more than 40 years experience from the multi corporation healthcare industry and scientific cardiovascular diseases clinical research communities from Minneapolis, United States of America

Industry Technical Experts:

- Amazon technical experts enable the core team to leverage the AWS platform by providing their technical expertise and resources to build the A.I. and Machine Learning workbenches to conduct future experiments.

The project stakeholders' characteristics were very diverse from the perspective of cognition, knowledge and expertise, motivation and interest, belief system, and language. Therefore, our first challenge was the need for a process to align the communication between the clinicians and the other stakeholders to support good quality requirements elicitation and ultimately a good model. We chose existing approaches, the WSD method and emotional goal modeling as our primary method for requirements elicitation and modeling, and explain in detail how and why below.

B. Existing approaches

WSD aims to understand how the computer system and the human system can be most productively integrated to improve efficiency in an organization (machine-human mixed initiatives). The concept of "system" here refers to a broad analysis when thinking about product requirements that must include policy, work practices, and tools, thus shifting from a single attribute of user requirements model to a broader understanding of practices — what people actually do, including practical constraints on the use of tools, communications, and problem-solving[9]. WSD methodology creates the modeling of how work is carried out (e.g., how in-clinic device check-up is carried out) and simulated with "What-If" scenarios by the use of Brahms modeling and simulation tool [9]. In particular, WSD requirements are used to redesign workflows, which would result in a new WSD model to be simulated to output a series of work system simulation behaviors before development begins. It applies ethnography (observation) methods and interviews to capture and model work practices. The modeling reveals which aspects of the work practice might be improved by tools (i.e. software agent automation) used within the existing system.

Emotional goal modeling involves developing and modeling functional goals of the system alongside identified quality

and emotional goals linked to identified functional goals. Emotional goals include both positive emotions and reinforce areas of the target system that should support/be emphasised, and negative emotions to areas in the target system that should be minimised or mitigated. The goal model becomes a valuable tool to use during discussions with stakeholders to provide an overall picture of the system in terms of the goals (functional, quality, and emotional) and the roles associated with these goals. It also represents how each functional goal can be further decomposed and shows the link between quality, emotional, and functional goals. The model also identifies the quality goals and emotional goals attached to each particular functional goal for different stakeholders.

V. Choice of Requirements Engineering Approach

We detail the requirements engineering approaches that we used and why we chose these approaches for this project.

A. WSD requirements elicitation and analysis

The foundation of WSD lies in the Brahms modeling and simulation tool. This provides its own Brahms Language to elicit and model requirements of people, tools, and activities into software agents for workflow redesign for future tool design that fits within people's work practices. In our case, we have adopted the requirements elicitation and analysis method that applies a conceptual framework using Brahms Language. The conceptual framework allows us to elicit empirical work practice (observation and interview datasets) into an analysis of the workplace. Moreover, the framework is designed on the theoretical foundation of human cognition theory - situated cognition [15], therefore basic aspects of cognition defined as part of the framework itself are elicited during the requirements process.

This requirements approach, in our view, is the most applicable to solving our system workflow design challenge presented by the stakeholders discussed above. First, it provides a systematic approach using empirical data for a person with a technical background (i.e. software engineer, technologist) to elicit requirements in a complex, natural workplace setting considering aspects of human cognition. Secondly, the conceptual framework structured analysis allows us to model and simulate by the use of a simple tool such as Microsoft Excel "What If"' scenario for informed- design specification of the health App that fits within the work practice setting.

However the limitation of the approach is that it requires the need to conduct ethnography and model the work practices in an agent-based language for requirements analysis.

B. Emotion-informed requirements elicitation technique using personas

Digital Health systems include the design and development of mHealth applications. The application is central in enabling the remote interaction (i.e., communication) between HF clinic workers and HF patients for effective intervention, as well as for patient self-management. Numerous studies report that engaging chronic disease patients in the long term use of an mHealth App is very challenging [16]. The challenge for our HF mHealth App is to elicit requirements that capture functional features as well as non-functional requirements within the context of patients day to day living with the HF disease. Thus, we felt it is very important to understand the emotional goal that patients would like to attain from the use of the App that supports them better in living with the disease, thereby engaging them in long-term use of the App. We refer to the definition by [8][17] of emotional goals, used interchangeably with affective or cognitive requirements from the system, to help emphasise positive user emotions and reduce or eliminate negative user emotions when using the mHealth solution.

As noted above, our demographic patient population is very diverse with broad representation across rural locale, language, culture, and age. To address this we chose to use an emotion-informed requirements elicitation technique using a persona. Using set of representative personas would help us to elicit and capture the multiple viewpoints in the use of the App. Personas help us to identify the user motivations, expectations, and goals for using the system. Although fictitious, personas bring users to life by giving them names, personalities, and often a photo[18]. Designers use them, developers, project participants, and others to get ideas for the design of products, I.T. systems, and services [19].

This approach is applied by using face to face interviews which are qualitatively analysed using thematic analysis to elicit common emotions in the group studied. The elicitation is only as good as the analysis and ability to elicit the emotions and requires specific expertise which can be a limiting factor.

C. User Stories

User Stories [20] are a popular method for representing requirements using a simple template such as *"As a role, I want goal, [so that benefit]"*. They are short, simple descriptions of a feature told from the perspective of the person who desires the new capability, usually a user or customer of the system. The end-users ideally are the ones who create their own User Stories. Typically, User Stories are often written on index cards or sticky notes to facilitate planning and discussion, strongly shifting the focus and concept in the use of User Stories as "artifacts" to build common ground [21] by encouraging end-users and software team to discuss them.

Another important feature of User Stories is the acceptance criteria. Acceptance criteria defines how a particular feature used from an end user's perspective. Most importantly, the user story informs the software team the conditions that will increase the success of the feature, based on user story acceptance testing.

We chose to use User Stories because they allowed us to use a template that was able to explicitly extract key features and functionalities of the mHealth App. The non-technical language convention made it easier for non-technical users to conceptualize an action that he/she was able to do with the "tool" while capturing the expectation of the users (i.e., acceptance criteria). Therefore in our work, User Stories were

demonstrated to capture the mHealth app functionalities as well as the emotional goals (i.e., as one of the acceptance criteria).

User stories however are limited in the vocabulary used to capture requirements.

D. Stakeholders selection for initial requirements elicitation process

Since this was the first time that Digital Health systems were developed for our cardiac centers, we took an empirical and iterative approach akin to Agile software development. We chose to involve and engage our stakeholders not only as part of the end-users requirements elicitation process but also as part of the team. We engaged our stakeholders after the requirements process to get feedback on how the process could be improved to better align the communications between the two groups. This meant that our requirements process was improved at each iteration by and with our stakeholders.

We decided at this initial stage, to engage the healthcare workers at the two of the cardiac centers' HF clinic located in East Malaysia. We chose the healthcare workers because these would be the end-users in using the Digital Health systems in managing alerts and remote patients' intervention. Furthermore, some of the healthcare workers are involved in broad qualitative HF research with patients. Thus, they had an understanding of the different patient population demographic challenges of people living with HF. Although producing the persona using healthcare workers has an increased potential to introduce bias, it would be most likely to be a bias based on real experiences and perceptions of the types of patients that they usually encounter including the major challenges that are discussed during clinic visits. For the subject matter expert in managing the patients with implantable devices, we involved an EP cardiologist in providing us with requirements for the ML development and features of the App required from an expert end-user perspective.

VI. Results - Requirements Elicitation Process

We presented the **results of our approach**, a requirements elicitation process in the later subsections as follows. First we described the kick-off meeting among all stakeholders. Then we described the elicitation process and artifact that were adapted - i.e the questionnaires and the User Stories templates from existing approaches.

A. Kick-off meeting

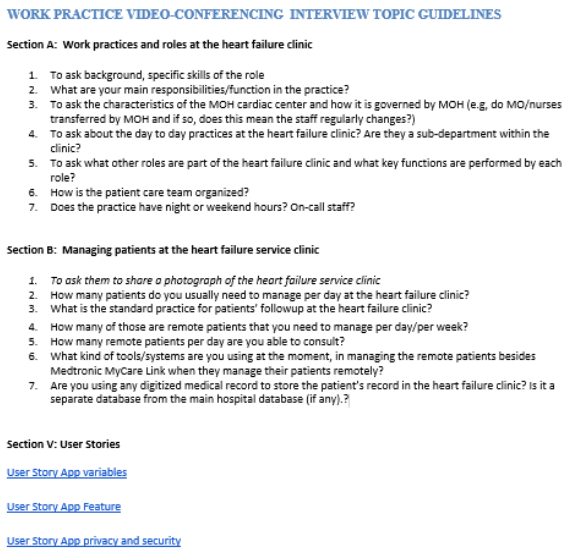
The MOH cardiac centers involved in the project were distributed across Malaysia and therefore we had to consider several constraints such as logistics, cost, and resources to conduct the combination of elicitation techniques (longitude observation, interviews). Thus, instead of using the combination of techniques, we focused the goal of the elicitation technique in developing a set of categorized questionnaires. We conducted the questionnaires as an open-ended interview via the video-conferencing system. The questionnaires included requesting from the healthcare workers samples of artifacts used as part of the HF clinic work practices. Below were the set of steps applied to prepare the stakeholders (i.e., healthcare workers).

- The general requirements process was made transparent to the healthcare workers via email. It included the rationale behind choosing the process, including indicating at exactly which processes that the healthcare worker's engagement required.
- A kick-off meeting among the two groups included the requirements' engineer and software development team to re-instate the design of the requirements process, including the future output from the process.
- The set of questionnaires was sent soon after the kick-off meeting.
- The requirements process began.

During the kick-off meeting, the consultant EP cardiologist gave very high-level requirements on what they would like to have on the mHealth App. It included who should use it, the demographic of the patient population, including the "variables" that they would like from the patients to make informed decisions. Certain decisions regarding persona development made during the meeting.

B. WSD Requirements elicitation process

Following the conceptual framework of Brahms language, our set of questionnaires thus focused on capturing the sequences of work practice activity in the management of patients at the HF clinic. We show an excerpt of the questionnaires we developed shown in Fig 1.



WORK PRACTICE VIDEO-CONFERENCING INTERVIEW TOPIC GUIDELINES

Section A: Work practices and roles at the heart failure clinic

1. To ask background, specific skills of the role
2. What are your main responsibilities/function in the practice?
3. To ask the characteristics of the MOH cardiac center and how it is governed by MOH (e.g, do MO/nurses transferred by MOH and if so, does this mean the staff regularly changes?)
4. To ask about the day to day practices at the heart failure clinic? Are they a sub-department within the clinic?
5. To ask what other roles are part of the heart failure clinic and what key functions are performed by each role?
6. How is the patient care team organized?
7. Does the practice have night or weekend hours? On-call staff?

Section B: Managing patients at the heart failure service clinic

1. *To ask them to share a photograph of the heart failure service clinic*
2. How many patients do you usually need to manage per day at the heart failure clinic?
3. What is the standard practice for patients' followup at the heart failure clinic?
4. How many of those are remote patients that you need to manage per day/per week?
5. How many remote patients per day are you able to consult?
6. What kind of tools/systems are you using at the moment, in managing the remote patients besides Medtronic MyCare Link when they manage their patients remotely?
7. Are you using any digitized medical record to store the patient's record in the heart failure clinic? Is it a separate database from the main hospital database (if any).?

Section V: User Stories

User Story App variables

User Story App Feature

User Story App privacy and security

Fig. 1. WSD interview questionnaires with User Stories embedded

The questionnaires and the User Stories template were uploaded on a team drive shared with the healthcare workers. In particular, we gave attention to the sequence of the process designed. We only showed the user story after the interview

session, included as links—the healthcare workers directed to the User Stories template after the interview by sharing our screen. We felt it was very important to show the user story after the WSD interview to provide a context for the clinicians to conceptualize how the App can be used within his/her work practices. The User Stories template for the elicitation of healthcare providers' mHealth App was called the "Doctor App". We created the following user story template for the Doctor's App, shown in Fig. 2.

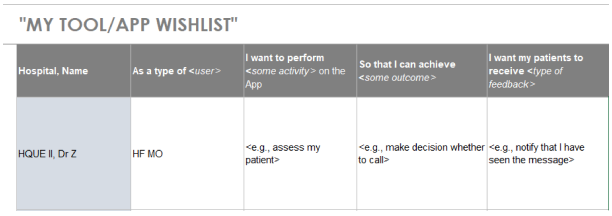
AGILE USER STORY

My Wishlist

Hospital, Name	As a type of *<user>*	I want to know *<type of patient information >*	so that I can *<achieve some goal>*	The information for me is *<Specify level of priority to have, 1 = good to have, 2= must have, and 3= nice to have>*
PJS, Dr X	Cardiologist EP	<e.g., breathlessness, blood pressure, etcs, diet, diagnosis>	<e.g., remind my patient>	<e.g, 1>

Fig. 2. The Doctor's app User Story template

Four categories of User Stories were developed and ordered on a hierarchy akin to a moment-by-moment contextualization: i) "User Story variables" ii) "User Story HF predict ML" iii) "User Story App Functionality" including iv) "User Story App Privacy and Security". Each user story category was defined from the perspective of a type of action to capture possible action(s) that the clinic staff might be required to take remotely using the App. Once again, we emphasized on capturing "sequence of activities". The acceptance criteria were instead defined as "outcomes" because the goal of patient management is to improve the outcome of patients (clinical measurements and quality of life). We show an excerpt in Fig. 3 for the user story category "Doctor App's Functionality."



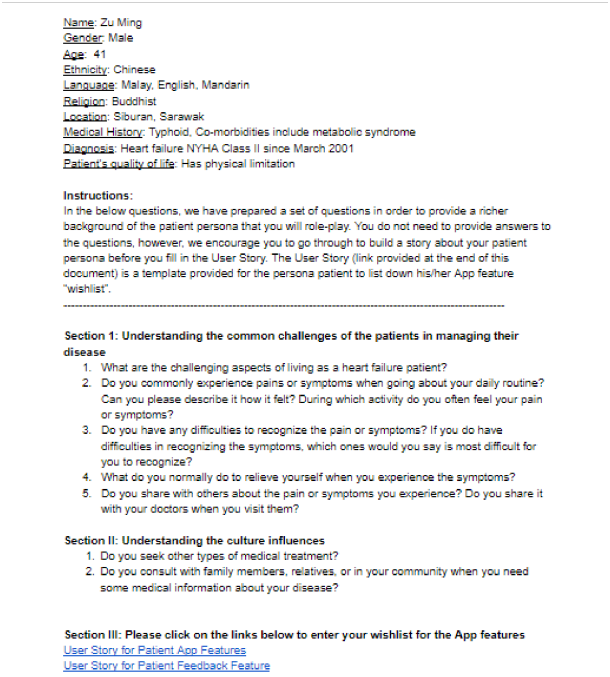
"MY TOOL/APP WISHLIST"

Hospital, Name	As a type of *<user>*	I want to perform *<some activity>* on the App	So that I can achieve *<some outcome>*	I want my patients to receive *<type of feedback>*
HQUE II, Dr Z	HF MO	<e.g., assess my patient>	<e.g., make decision whether to call>	<e.g., notify that I have seen the message>

Fig. 3. User Story for Doctor's App Functionality template

C. Patient's App emotion-informed elicitation technique using User Stories and persona

As previously mentioned, the personas were developed with the clinicians who were informed by their patients' demographic and understanding of the clinical population being targeted. We let the healthcare workers decide among themselves who was to play the persona. Two HF clinic medical officers, a medical officer HF researcher, and a nurse from both centers were selected to play the persona because of their frequent interaction and close management of patients in the clinic. In particular, the medical officer HF researcher involved in quantitative clinical studies with patients was very valuable as they brought insights about the patient population and what were useful to elicit. Thus, the persona characteristics included name, location, ethnicity, religion, medical history, heart failure, clinical diagnosis, including patients' physical limitations following NYHA heart failure classification. A set of open-ended questionnaires followed for the persona role play. The questionnaires categorized into two simple sections: i) to understand patients' struggle in living as an HF patient, and ii) understanding the cultural influences. An example is shown in Fig. 4.



Name: Zu Ming
Gender: Male
Age: 41
Ethnicity: Chinese
Language: Malay, English, Mandarin
Religion: Buddhist
Location: Siburan, Sarawak
Medical History: Typhoid, Co-morbidities include metabolic syndrome
Diagnosis: Heart failure NYHA Class II since March 2001
Patient's quality of life: Has physical limitation

Instructions:
In the below questions, we have prepared a set of questions in order to provide a richer background of the patient persona that you will role-play. You do not need to provide answers to the questions, however, we encourage you to go through to build a story about your patient persona before you fill in the User Story. The User Story (link provided at the end of this document) is a template provided for the persona patient to list down his/her App feature "wishlist".

Section I: Understanding the common challenges of the patients in managing their disease

1. What are the challenging aspects of living as a heart failure patient?
2. Do you commonly experience pains or symptoms when going about your daily routine? Can you please describe it how it felt? During which activity do you often feel your pain or symptoms?
3. Do you have any difficulties to recognize the pain or symptoms? If you do have difficulties in recognizing the symptoms, which ones would you say is most difficult for you to recognize?
4. What do you normally do to relieve yourself when you experience the symptoms?
5. Do you share with others about the pain or symptoms you experience? Do you share it with your doctors when you visit them?

Section II: Understanding the culture influences

1. Do you seek other types of medical treatment?
2. Do you consult with family members, relatives, or in your community when you need some medical information about your disease?

Section III: Please click on the links below to enter your wishlist for the App features
User Story for Patient App Features
User Story for Patient Feedback Feature

Fig. 4. Persona based-interview questionnaires using User Story

Role play by the healthcare workers for the interview was used as an instrument to build a context for them to recall patients' struggles from a patient's perspective. At the end of the interview, we directed the healthcare workers to the User Stories. We maintained the same sequence in using interviews, then followed by User Stories as done for the WSD requirements. Similarly, the interview questionnaire and User Stories template uploaded to a team drive. The User Stories categorized similarly to the Doctor's App User Stories to build a hierarchy akin to a moment by moment conceptualization in how the App could be used to capture functional requirements that included communication, and emotional goal. We emphasized communication goals along with the emotional goal-based on the WSD interviews, in which the HF clinic work practices were defined around coordination and communication. Fig. 5 shows a patient app user story example. We also included a category for privacy and security user stories in order to capture such non-functional requirements. A patient app non-functional requirement example is shown in Fig. 6.

Patient Diagnosis	I would like an App that let me <do what when I am>	so that I can <achieve some communication goal>	where I can feel <achieve some emotional goal>	Preference of my data input
HQUEII, Fatimah Mansuh	HF NYHA Class II	<e.g., a tick that my self reporting symptoms is shared with nurse>	<e.g.,assurance that my nurse knows my situation>	<e.g., by press button>

Fig. 5. User story template for Patient App

Hospital, Name	Patient Diagnosis	I feel my personal data is safe when I log into App <specify which method>	There are times, I want to share my information with others <specify what information, with who, and the motivation>
HQUEII, Rawi Si	HF NYHA Class II	<e.g., using my IC number>, using username and create own password	<e.g., share my symptoms with my daughter so she can keep track of my disease> - no (preference face to face)
		<e.g., using my own password>	<e.g.,share what the doctor/nurse advise so they can support me better>

Fig. 6. User story template for Patient App non-functional requirements

VII. Evaluation of Results

We report on the data that we have collected and analyzed applying our chosen requirements' engineering approaches in this HF mHealth app case study to date.

A. WSDs

The WSD interview was audio-recorded and transcribed. We focused on the management of patients during the HF clinic days/hours. Using a sequence of activities as a unit analysis, the narration by the healthcare workers focused on how the team coordinates to manage and assess patients in the clinic. Importantly, the results suggest that communication is central in managing the patients. For example, when asked to describe the work practice at the HF clinic, the healthcare worker narrated below:

"Talk to patients in regards to the medication - why they are on it, and let them understand their body weight, fluid control, pharmacy to talk to them how to titrate to decrease/increase medication on themselves, and if other and how to pass urine, they can monitor body weight, and they can manage by themselves, and be aware if symptoms develop."

Similar data were captured across the two centers in the standard practice in the management of HF patients. Patients needed to be reminded and educated about how to manage his/her symptoms. This also lead us to identify and understand the need for important medical concepts such as "titrate" in the management of patients.

Data analysis revealed the basic functional requirements required in the Patient App. It also revealed an opportunity for how we can better design the App to allow a more real-time dynamic interaction with users. It was evident to see that healthcare workers must always be in the loop in verifying the remote self-assessments of the patients.

The interview questionnaires directed at understanding how artifacts used in the management of patients with devices focused on two aspects: 1) eliciting what do they look for in the artifacts (i.e., variables), and ii) how the variables are (i.e., information) used in making a decision. We show an excerpt below and in Fig 7:

"...So an MO looks at printed device report, the device report put into a case notes by a technician. We look at the case notes and then interpret the device data. We look for arrhythmia, heart block, malignant, look at the battery, how long it will last, and look if they have A.F. So if you see, top right corner he had V.T. about 136-140bpm. It doesn't fall under the VT zone(set at 160bpm) ,hence no therapy(shock) delivered"

Data also revealed key functional (i.e., types of variables included on the Doctor's App) and non-functional requirements (i.e., how the information presented that fits with their cognition model of the domain). It also revealed opportunities for how other types of information from the Patient's App that can be used to augment existing data provided by the devices.

The WSD requirements approach enabled us to elicit basic functional requirements. We define basic requirements to mean the fundamental functionalities included, as part of a basic guideline for patient self- management. It also revealed "What-Ifs" opportunities using ML/AI approaches to improve existing work practices.

Hospital, Name	As a type of <user>	I want to know <type of patient information >	so that I can <achieve some goal>	The information for me is <Specify level of priority to have, 1 = must have, 2= good to have, and 3= nice to have>
PJ	HF MO clinic (Dr Y)	patient symptoms (they feel tired, yes/no, breathelss, yes/no., fatigue, leg swelling,blood pressure, heart rate, weight)	adjust medication (to remove the weight), and to know latest functional/clinical status , to know if they go into decomposition (to give plan to them)	1

Fig. 7. WSD interview transcription

B. User Stories

The user stories gave us a much clearer picture of the key functional requirements. For example, that our mHealth solution should provide the patient with functionality for them to record symptoms, including vital signs. The functionalities relate to HF clinic practices, and the guideline used to make patient assessments for the treatment and management plan. The healthcare workers WSD and user story had more or less the same kind of requirements across the two centers. Thus, it was quite clear on what is required from the healthcare workers' perspectives what they needed to have as variables from the Patient App to help them make remote assessments.

C. Emotional Goals

Our user story design included a "communication goal," which we felt was important along with emotional goal. WSD requirements data highlighted that central to patient management is effective communication between the two stakeholders. The clinician communicates to get certain information; likewise, the patient communicates with doctors, in general, to get some advice.

As user stories were used in relation to the interview questionnaires and personas, they allowed us to capture the struggle that patients usually go through in living as a heart failure patient. Therefore, it was quite explicit in giving us functional requirements, for example, that we needed to have an App functionality that can track and record specific variables when they are outside.

The communication goals, on the other hand, specified by the patient, suggested that we should be focusing on improving patients' quality of life. The goal of the patient communicating was to get information that can help them understand their condition to improve their quality of life.

The emotional goal expressed a combination of "feelings" but also to help them make informed-decisions whether their condition warrants an earlier clinic visit. The finding was interesting, perhaps suggesting that feeling of anxious whether they should see a doctor earlier is one of the patient's emotional goals that needed fulfilling. It gave us also an interesting evaluation that emotional goal leads to decision making action. Fig. 8 shows an example.

Hospital, Name	Patient Diagnosis	I would like an App that let me <do what when I am >	so that I can <achieve some communication goal>	where I can feel <achieve some emotional goal>	Preference of my data input
PJS, Zu Ming	HF NYHA Class II	to record my walking distance/speed/steps when I walking at home/outside.	for home self monitoring and for doctor to know my frequency of hf symptoms	so that I feel reassured when I do not have new hf symptoms	press button for my symptoms/assessment of my everyday activities-preferably with graphic/simple understandable terms.
HQEII , Lukas Palem	HF NYHA class III	record symptom mainly difficulty of breathing.	I need to know how bad my condition now	I want to see when I should go and see my doctor	can capture automatically, so that I no need to do key in again because most of the time I have difficulty of breathing when my condition is bad.

Fig. 8. Patient's App User Story emotional goal requirements

D. Human-centric Issues

The user story field on "preference of data input" was to capture potential human-centric issues. In particular, the language and cognition used by patients to describe symptoms and pain. Thus the user interaction between the patient and the mHealth App design must be intuitive and easy for the patient to enter their data without having to do it repeatedly. However, given that the patient demographic is diversified with different patient groups having their dialect- thus, the language and cognition will influence how symptoms and pain experienced and described. We captured non-functional requirements including those around the issues of privacy and security concerning the patient's data. We included this explicitly as part of the user story because a patient's data privacy act is the most important constraint we must consider. Fig. 9 shows an example of such non-functional requirements captured.

Fig. 9. Patient's App User Story non-functional requirements

We focused specifically on data-sharing to elicit privacy and security requirements based on a study we have conducted with patients (direct users) on ChemoCare App design in another hospital. We found that in our Malaysian culture, patient management involves caregivers' involvement. Often, the family would help in the self-management. The sharing of data would lead to privacy and security issues and specifications in the design aspect, such as roles, authorization, and vulnerabilities etcs. Using the user story, we could identify other types of indirect users (i.e., stakeholders) that can have access to some of the patients' data [ref].

E. Example Requirements

We are not able to share all of the system requirements elicited, due to confidentiality requirements. However, to give an idea, some of our elicited requirements for the application include:

- App should capture variables from patients in a format that follows the heart failure passport;
- App should capture patient's symptoms and vitals like blood pressure and heart rate;
- App should capture the results of the quality of life assessment;
- App should be able to be used as a personal record system and self management tool even if they are no longer remotely monitored.

VIII. Discussion

The use of User Stories and persona for patient mHealth App in a contextualized manner by the WSD approach worked well for us in eliciting the key App functionalities. Using emotional goal modeling from a broader perspective of work practices helped to create a better fit and more acceptable Digital Health system for HF patients and clinicians. The emotional goal requirement results, in particular, showed us that we could use it as an "acceptance criteria", that the design end- goal should be about providing the patient with a feeling of assurance or feeling of being "taken care of".

Thus the **strength of our approach** is by the use of user stories artifact situated into the context of HF-related work practices. We were able to capture requirements from a healthcare provider's perspective while creating domain knowledge in the remote management of patients. The emphasis on creating context for the patient persona by using combination of interviews and the User Stories emotional goal enabled us to capture the "acceptance criteria", including the challenges in a patient self-management, knowing when to seek medical care.

However, there are certain aspects of our approach that **did not work as well as we had hoped**. First, using emotional goals for the HF clinic staff did not come to full fruition. The clinic staff struggled to articulate how emotional goals, i.e., how they felt about something that is part of their work practices at the clinic. In the end, we decided to forgo the elicitation of emotional goals for the Doctor's App. This result suggests that in work practices of the clinic staff, they remain objective in their relationship with the patients. Put another way, the term 'goal' used in the user story with emotions, is not part of a professional goal-based approach trained in the clinician.

Second, we had quite the opposite results to emotional goal modeling for the Doctor's App in terms of the emotional goals for the patient personas. These revealed that although it did work in eliciting patient personal emotional goals, the results intertwined the emotional and decision-making needs. We hypothesize that there might be a cultural influence when it came to expressing or articulating emotional goals. In Western

or individualist cultures, high arousal emotions are valued and promoted more than low arousal emotions. In contrast, in Eastern or collectivist cultures, low arousal emotions are valued more than high arousal emotions. Moreover, people in the East experience and prefer to experience low arousal emotions more than high arousal emotions [22].

Third, the user story for the category on "App functionality" managed to capture only one (1) functional requirement, although we had four (4) HF clinic staff that participated. The category asked the user to specify the type of activity that they wish to do using the mHealth App, and the objective they wish to attain. We hypothesize that the word "activity" used as a template in the particular user story category is a term not familiar with them. It could have been better replaced with the term "work practices", one with which they could all relate.

Therefore, a **weakness in our approach** is the language used in the User Stories. Although the User Stories artifact was effective in eliciting the App features requirements, it could be improved in the language used to write the User Stories. The language should be appropriate to patients setting when thinking about managing the disease and living with their disease.

Two key lessons were learned from our experiences to date. *First*, is the importance in understanding the language and cognition of the healthcare stakeholders when it comes to speaking about requirements. Language, not surprisingly is often the barrier to miscommunication, and misunderstanding. *Second*, from a software engineering practice, it is our practice to think in terms of goals in a discrete manner, where each functionalities should have a certain goal in using it. However this is not the case for the healthcare stakeholders in our study when framing the requirements. They think from the perspectives of situations, and a goal for them is majorly to improve patient outcome.

Thus, our key future direction is to focus more closely on involving our clinician stakeholders in improving the User Stories template so that they resonate with the language and cognition of the healthcare providers and patients within our culture setting. We did find that using the User Stories in general helped to bridge and align our communication process with the healthcare stakeholders when speaking about requirements.

Our future plan is to explore empirically with the stakeholders how we can improve upon the User Stories categories and language used that did not work so well. In particular, we want to elicit and specify if and how certain categories of emotions (feelings) influences or motivates patients in making certain decisions about their health. We want to translate the results into functional and design requirements that promotes long-term self-management. In order to further improve on this, we plan to conduct qualitative analysis by the use of interviews with the direct users (patients) in order that we can elicit while understand the patients' emotional experiences (difficulties) in living with HF.

Most importantly - perhaps central to our work is that we must collaborate with the healthcare stakeholders in translating the User Stories into the Malay language [23]. Careful thought must be given in the terms and language used especially to capture emotional goal that can be easily understood and connected with by our local patients. We foresee that this could reveal very interesting results as we have not come yet across a study that reports the use of User Stories in other languages besides English.

IX. Summary

This paper reports our ongoing project in Malaysia with the Ministry of Health Malaysia cardiac centers to address some of the barriers to continuous care for patients with chronic HF using Digital Health systems interventions.

Our project had two major aims. The first aim was to find a suitable requirements engineering approach that could align the communication process when speaking about requirements. Our project stakeholders' characteristics' extremely diversified from the perspective of cognition, knowledge and expertise, motivation and interest, belief system, and language. Therefore, our requirements engineering process need to supports good quality requirements to elicit and model from them.

The second aim was to find a requirements engineering process that could define a software system product that fits within a total work practice in the management of HF patient while considering the emotional aspects of patients acceptance in use of a novel Digital Health intervention systems. A recent position paper for digital health in cardiovascular diseases [13], outlined some of the same challenges we found in our work-study in Malaysia [12]. The authors outlined two barriers to the adoption of digital health in clinical practice.

First is the patient-related barrier that relates to user characteristics and health status, privacy, security and quality concerns, lack of personal motivation, and accessibility to digital resources. Most often, digital healthcare is added 'on top of' existing care rather than being designed to fit within the current care delivery. The authors gave an example of nurse-led telemonitoring programs for HF patients. The programs set up without reducing/ adapting the timing and frequency of conventional hospital-based appointments by the treating cardiologists at the hospital, thus increasing both the costs and time investments. Therefore, the authors suggested the need for a digital health workflow redesign that improves the physician-patient relationship. Maintaining the physician's time to serve primarily as a diagnostician and educator instead of doing actions handled through automated systems could enhance the relationship. Workflow redesign should be to individualize diagnostics and treatment better, facilitating patient data retrieval, simplifying real-world monitoring, and providing evidence-based guidance.

To achieve the two major aims of our project, our study applied WSD with personas, User Stories, and emotional goal modeling. The application of User Stories provided a tool for us to establish a common ground when talking about requirements. The overall requirements engineering process to include clinicians work practices helped develop our domain

knowledge of the future system. Application of our approaches highlighted the need to be sensitive to human-centric issues when adopting requirements approaches in our cultural setting (South East Asian). These issues become prominent for consideration because the system to be used by patients living with chronic disease - requires long-term management and thus meaningful use in the context of their day to day living. Thus, it requires a shift of perspective when designing a mHealth App for Digital Health intervention system, whereby we need to view that the mHealth application as a "tool", used in patient's day to day living as a HF patient, including in the everyday work practices of clinicians.

In summary, aligning healthcare stakeholders communication process with software team from our early results suggest the need to improve on our language use by understanding the cognition of the healthcare stakeholders. As we move closer in developing tools that impacts at a personal level of an individual use, especially in living with a chronic disease, it is important that language and cognition is taken into consideration. Finally, we recommend that using artifacts, such as User Stories is useful as a shared representational tool to build a common ground - in turn is useful in aligning the communication processes.

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References

[1] A.-Y. Chong, R. Rajaratnam, N. R. Hussein, and G. Y. H. Lip, "Heart failure in a multiethnic population in kuala lumpur, malaysia," *The European Journal of Heart Failure*, vol. 4, no. 3, pp. 569–574, March 2003.

[2] P. Ponikowski, S. D. Anker, K. F. AlHabib, M. R. Cowie, T. L. Force, S. Hu, T. Jaarsma, H. Krum, V. Rastog, L. E. Rohde, U. C. Samal, H. Shimokawa, B. Budi Siswanto, K. Sliwa, and G. Filippatos, "Heart failure: Preventing disease and death worldwide," *ESC HEART FAILURE*, vol. 4, no. 1, p. 4–25, March 2014.

[3] G. Y. Lam, "Heart failure in southeast asia: facts and numbers," *ESC HEART FAILURE*, vol. 4, no. 1, p. 46–49, March 2015.

[4] J. H. Lee, N.-K. Lim, M.-C. Cho, and H.-Y. Park, "Epidemiology of heart failure in korea: Present and future," *ESC HEART FAILURE*, vol. 4, no. 1, pp. 658–664, March 2016.

[5] A. A. Shafie, Y. P. Tan, and C. H. Ng, "Systematic review of economic burden of heart failure," *ESC HEART FAILURE*, vol. 1, no. 1, pp. 131–145, March 2018.

[6] A. Jovicic, J. M. Holroyd-Leduc, and S. E. Straus, "Effects of self-management intervention on health outcomes of patients with heart failure: a systematic review of randomized controlled trials," *BMC Cardiovascular Disorders*, vol. 1, no. 1, pp. 131–145, March 2006.

[7] N. Carroll and I. Richardson, "Aligning healthcare innovation and software requirements through design thinking," in *Proc. Int'l Workshop on Software Eng. in Healthcare Systems (SEHS 16*. IEEE, may 2016.

[8] K. M. Curumsing, F. Niroshinie, A. Mohamed, V. Rajesh, M. Kon, and J. Grundy, "Emotion-oriented requirements engineering: a case study in developing a smart home system for the elderly," *Journal of systems and software*, vol. 147, no. 2, pp. 215–229, feb 2019-01.

[9] M. Sierhuis and W. J. Clancey, "Modeling and simulating work practice: A method for work system design," *IEEE Intell. Syst.*, vol. 17, no. 5, pp. 32–41, 2002. [Online]. Available: https://doi.org/10.1109/MIS.2002.1039830

[10] M. Cohn, *User Stories Applied: For Agile Software Development*. USA: Addison Wesley Longman Publishing Co., Inc., 2004.

[11] M. Curumsing, "Emotion-oriented requirements engineering," Ph.D. dissertation, Swinburne University of Technology, 2017.

[12] N. N. Binti Abdullah, W. Clancey, A. K.Raj, Z. Md Zain, F. F. Khalid, and A. Ooi, "Application of a double-loop learning approach for healthcare systems design in an emerging market," in *2018 IEEE/ACM International Workshop on Software Engineering in Healthcare Systems, SEHS@ICSE 2018, Gothenburg, Sweden, May 28, 2018*, I. Richardson and J. H. Weber, Eds. ACM, 2018, pp. 10–13.

[13] C. Mathews, M. J. McShea, C. L. Hanley, A. Ravitz, A. B. Labrique, and A. B. Cohen, "Digital health: a path to validation," *npj Digital Med*, vol. 2, 2019.

[14] W. J. Clancey and R. Van Hoof, "The metabolic rate advisor: Using agents to integrate sensors and legacy software," *NASA Ames Research Center*, no. 9, may 2013.

[15] W. J. Clancey, *Situated cognition: On human knowledge and computer representations*. Cambridge university press, 1997.

[16] J. Wang, Y. Wang, C. Wei, N. Yao, A. Yuan, Y. Shan, and C. Yuan, "Smartphone interventions for long-term health management of chronic diseases: an integrative review," *Telemedicine and e-Health*, vol. 20, no. 6, pp. 570–583, 2014.

[17] J. Grundy, M. Abdelrazek, and M. K. Curumsing, "Vision:improved development of mobile ehealth applications," in *In 2018 IEEE/ACM 5th International Conference on Mobile Software Engineering and Systems (MOBILESoft)*. IEEE Press, 2008.

[18] L. Schneidewind, S. Hörold, C. Mayas, H. Krömker, S. Falke, and T. Pucklitsch, "How personas support requirements engineering," in *2012 First International Workshop on Usability and Accessibility Focused Requirements Engineering (UsARE)*. IEEE, 2012, pp. 1–5.

[19] B. Ferreira, G. Santos, and T. Conte, "Identifying possible requirements using personas-a qualitative study," in *International Conference on Enterprise Information Systems*, vol. 2. SCITEPRESS, 2017, pp. 64–75.

[20] M. Cohn, *User stories applied: For agile software development*. Addison-Wesley Professional, 2004.

[21] N. N. Binti Abdullah, S. Honiden, H. Sharp, B. Nuseibeh, and D. Notkin, "Communication patterns of agile requirements engineering," in *Proceedings of the 1st Workshop on Agile Requirements Engineering*, ser. AREW '11. New York, NY, USA: Association for Computing Machinery, 2011. [Online]. Available: https://doi.org/10.1145/2068783.2068784

[22] L. Lim, "Cultural differences in emotion: differences in emotional arousal level between the east and the west," *Integr Med Res*, vol. 5, p. 105-109, 2016.

[23] M. Kamalrudin, J. Grundy, and J. Hosking, "Maramaai: tool support for capturing and managing consistency of multi-lingual requirements," in *2012 Proceedings of the 27th IEEE/ACM International Conference on Automated Software Engineering*. IEEE, 2012, pp. 326–329.