USER-CENTRED DESIGN AND USABILITY EVALUATION OF A WATER QUALITY DETECTOR USING MOBILE APPLICATION

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ABSTRACT

Proper daily intake of water is one thing that everyone should be concerned about. However, the level of water hygiene in most places is highly sceptical of its health-promoting content. Many modern technologies can check the water content or ingredient well but most are expensive and difficult to found. The use of mobile application elements experience is a well-recognised method for achieving higher motivation and engagement in various tasks. However, there is limited documented knowledge on how to design a mobile application for water quality detector. In particular, the influence of additional interactive elements on the main course of training has not yet been explored. In this paper, we evaluated user requirement analysis, design proposed design and usability testing as well accepted by the participants and the components to be included were identified. An Android water quality detector mobile application was developed with a single design that meet all the requirements. Design, development, and evaluation were conducted using a user-centred approach, including context analysis, the design of mobile application principle mock-ups, the selection of game principles through a survey, the design of the game mechanics and GUI mock-up, and icon testing, and the performance of a summative study through user questionnaires and interviews. A summative evaluation of the developed game was performed with 12 of healthy participants and unhealthy participant (ages 20 to 69) in a controlled setting. The results confirm the potential of mobile application for motivating people to engage in proper daily intake of pure water content.

Index Terms: Water Quality Detector Using Mobile Application, Health-Promoting Content, People Motivation, Usability, Mobile Application for Health.

INTRODUCTION

Water is one of the most important necessities of our daily life [17]. Without water, we would surely die of thirst. Water quality from rivers is as importance as the reason for these water sources is often used for many things such as: drinking water and domestic water supply, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and human ways, or other economy to use water [16]. Most places like big and developed cities have easy access to clean water. Urban residents do not have to worry about water shortages in their homes. This situation is different for people living in rural areas. Residents here have easy access to water sources in their area such as rivers and springs. However, they are hesitant to use the water source for their daily life. This is because it is feared that the water source has been contaminated with toxic waste or other substances that could harm a person's health. Based on research survey, over 90% of Pacific Northwest respondent considered clean sources of water is a high priority [1].

There are many causes of water pollution around the world especially in Asia. One of the main causes of such pollution is from humans. Compared to other continents, Asia has the highest number of polluted rivers due to widespread human pollution. Water pollutant can be defined as physical or chemical factor causing aesthetic effects on aquatic life and those who consume water [18]. Most people throw food and garbage out of their homes into the river without considering the consequences of the river's cleanliness. In fact, there are willing to dispose of toxic waste that endangers the ecosystem into clean canals or rivers. Surface water should be free of contaminants such as debris, oils, substances that can cause adverse effects on humans, fish and other animals and plants [2]. According to a study, an estimated 1000 children die in India every year due to severe water pollution [3]. This makes it difficult for rural people to get clean water. According to a study, diarrhoea is the second leading cause of death worldwide among children under the age of 1.5 million people every year [4]. Monitoring and evaluation are possible be done first before having a definite plan on how to exterminate water pollution problem [5].

Smartphone is one the most important thing that an individual should have beyond their reach at all time, especially for youngsters. It is often used by peoples for social, entertainment, and even educational purposes. The share of Americans owning smartphones has increased substantially since 2011, when Pew Research first began examining smartphone applications. Today, nearly two-thirds (64%) of adults in the United States have smartphones, up 35 percent in 2011. Young adults and those with higher education are among the most likely to have a smart phone [6]. Meanwhile, in Malaysia, based on 2017 Malaysian Communications and Multimedia Commission (MCMC) Hand Phone Users Survey, the amount of smartphone users continues to rise. The rate of the users grew by 7.2% from 68.7% in 2016 to 75.9% in 2017 [7].In America, about sixty percent (62%) of smartphone owners used their phones to get health information last year,

same as the percentage who said they had used their smartphone for online banking. Americans not only use their smartphones to find employment information, but they also use their phones to apply job [6]. In Malaysia, the percentage of smartphone users who use their phone to surf the internet has increased by 26% since 2012 [8].

Some studies on water quality monitoring system [9-13] have running with promising results. Water quality monitoring system has been developed consists of sensors, and smartphones. Therefore, we create an application that can check the quality of water. This application requires users to have a water detector. The user will register their account within the application. After registering, the user will fill in the user's health information. This is to facilitate the application to make recommendations on the amount of water to be consumed in a day and the type of water that the user can drink. Then, the user must connect the application with the water detector via 'Bluetooth'. After the device has been successfully connected, the user has to dip the device into the water they wish to inspect. Once the device is ready to check the water, the results of the water are displayed in the application. The results are divided into five sections: pH reading, water temperature, water turbidity, water content and dissolved oxygen level. In the water content section, the app displays the percentage of content in the water such as minerals and oxygen.

For a new system to have real value and impact on the targeted user, the first step is to set up its usability [14]. Usability testing can include various combinations of methods, such as the involvement of experts and targeted users during the evaluation, to generate ideas for system improvements [15]. In this research, we conduct usability evaluation on our water quality application, 'ACUA checker'. Our application will be evaluated by 12 candidates ranged by 21 to 60 years old. The evaluation will be divided by two groups that are healthy and unhealthy participants.

METHODOLOGY

1.Identifying User Requirements

We run an experiment to identify user requirements on the water quality detector mobile application at a Water and Environmental Engineering Department Universiti Teknologi Malaysia Johor Bahru and among the public through advertisement. Some of the users are related to water quality management and others are community that use water in everyday life. The experiment involve two main type of user groups, healthy user (did not diagnosed with any disease) and unhealthy user (diagnosed with diseases). The age range in the two groups is between 21 to 60 years old. We collected the information based on the 10 questions through questionnaire done by the 12 users (unhealthy and healthy people) via paper and online questionnaire distributed to them. Then, mobile application-based method was chosen to survey the time taken to complete each task of the application. Results from identifying users requirements experiment shows that healthy people response to the task are a lot faster compare to unhealthy user. This is probably because healthy people stands from a younger age compare to unhealthy people. Some of the reasons users took a

lot of time to complete the task is because of the certain task may consume times for better understanding for each user. Finally, the ability for independent test shows that not many differences between the two main groups.

2. Apparatus Requires

The required apparatus for using water quality detector are smartphone, ACUA Checker application and ACUA water sensor.

3. User interface prototype design

For the experiment design, we decided to use Adobe XD to create a user interface for our mobile application design. Many buttons, slides and more gadgets were included in the software developments kits. The proposed prototype was designed based on a principle and evaluation list. Then the HTA of the proposed prototype has been displayed.

4. Procedure

This experiment design is carried out on two main groups of the user which is healthy participants and unhealthy participants. There were 12 total participants that were divided into 2 groups which are 7 participants from healthy group and 5 participants from unhealthy group. Most of our participants are willing to take part as our tester and show positive attitude. Those who are from unhealthy group really show their interested in this water quality application. After the testing process, the participants will require to give their opinion and suggestion to create better application. The platform for our application is a mobile application. There are 3 main tasks for this water quality detector application. First main task is Health where user need to give their medical information such as blood type, medical condition and others related. All of the users need to fill all this requirement for this application can detect and give best suggestions of water suits the users. Next, Bluetooth connection where users have to connect their smartphone to water sensor. Application cannot be run if there no connection between the smartphone and water sensor. Last but not least, is result. In results the application display all the data based on the test previously. The instruction is given to the participant on how to use the water detector application. The participants are required to have at least a knowledge on how to use a smartphone function such as Bluetooth. Below are the three tasks that was assigned to the participant:

Task 1: User fill up Health Information.

Task 2: User have to connect the smartphone and the water sensor using Bluetooth connection.

Task 3: Application display all the data.

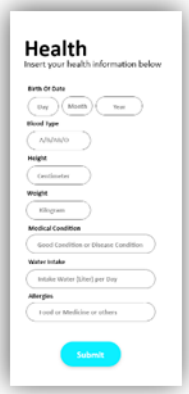

Figure 1. Performing Task 1

Figure 2. Performing Task 2

The participant was observed when performing the given tasks. The goal of the task is to determine the interval time is taken for each task to be completed

RESULT

1. User Requirements Analysis

Twelve participants were scheduled for the water quality FGD, all of them participated. Twelve participants were selected; only five participants in health problems FGD. Characteristics of the participants are displayed in table 1. The outcome of the FGD is divided into five themes – lifestyle and self-monitoring, education & awareness, motivation and commitment, social support and coaching, and technology. These themes emerged from the response of the participants.

1.1 Technology

When technology was mentioned, positive response was given by the 12 participants. About 86% of the participants own a smart phone. Some of them download pH tracker app from the Google Playstore or AppStore and use it daily.

Four participants browse water quality and health related websites by using the search engine Goole or Safari to find information about their drinking water, especially on those which are suitable for health problem person. One of the participants, who is active in sports and has a Facebook account, follows some articles shared by his trainer and doctors on water quality and the effect towards health. Since then, he always making sure the water quality is in good condition before consuming it.

Five participants claimed that the information they got come from the Internet through WhatsApp. After reading the articles, they feel motivated and share it to the others for awareness.

The participants shared that usage of smartphones and Internet really helps them in many ways. They said an application that detect the quality of water will be a good assistant to monitor their daily water consumption. An unhealthy participant shared her opinion that the applications should be multitasking so that many people will like to use it. In addition, some of them also mentioned that the application should give them reminders at a specified time

Components of the Proposed Water Quality Detector Application: The participants mentioned the important components they wanted in the application by ranking the components. The priorities of the water quality detector application components have been divided: healthy participant and unhealthy participant. Priorities here means the most important to least important components from participant's viewpoints. Table 2 shows the percentage of people who had healthy participant and unhealthy participant for each component. Figure 1 illustrate the comparison between the people who had healthy participant and unhealthy participant on their priorities.

Category	No (%)
Age (Years)	
20-29	2
30-39	4
40-49	2
50-59	3
60-69	1
Gender	
Male	7
Female	5
Ethnicity	
Malay	5
Chinese	4
Indian	3
Health Problem	
Yes	5
No	7

Table1. Characteristics of the 12 participants

Component of Water Quality Detector Application	Healthy Participant (%)	Unhealthy Participant (%)
Self-monitoring	100	95
Water pH Measurement	100	98
Activity Planning	98	83
Mineral Percentage in Water Measurement	97	92
Personal Data	96	85
Water Turbidity Measurement	90	85
Water Temperature Measurement	89	72
Amount of Dissolved Oxygen in Water	84	77
Goal Setting	82	64
Online Education	79	60
Forum	75	58
Alerts/Reminders	72	55
Social Support	71	55
Coaching	70	50
Reward System	57	48

Table 2. Priorities of healthy participant and unhealthy participant on water quality detector application components

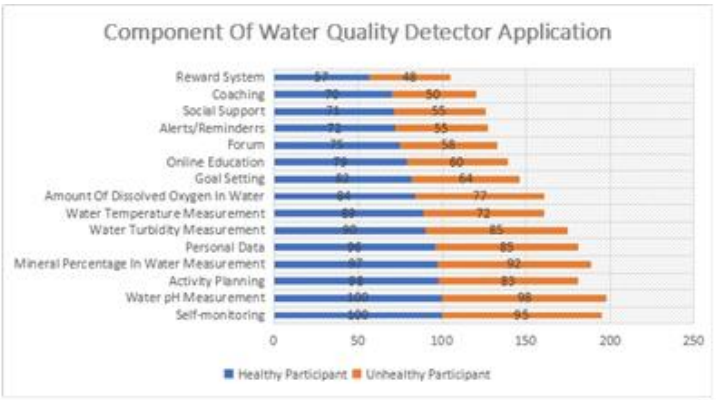

Figure 3. Comparison between healthy participant and unhealthy participant priorities on self-care application components.

Based on the participants' choices, self-monitoring and Water pH Measurement stays as the top priority for both groups. This followed activity planning, mineral percentage in water measurement, personal data, water turbidity measurement, water temperature measurement, amount of dissolve oxygen in water, goal setting, online education, forum, alert/reminder, social support, coaching and reward system. For non-health problem, water pH measurement is followed by self-monitoring, mineral percentage in water measurement, personal data, water turbidity measurement, amount of dissolve oxygen in water, water temperature measurement, goal setting, online education, forum, alerts/reminder, social support, coaching and reward system. It is interesting to note that activity planning is not being considered as one of top priority for non-health problem compared to health problem. Healthy participants have chosen self-monitoring, water pH measurement and activity planning as their top priorities because they would like to have an application that monitor someone lifestyle and recommend activities for them to reduce their health problems.

The reward system is the least priority for both the groups. They mentioned that they should be self-motivated through their mindset about their own health and not through any reward system. Online education, social support and forum are in higher priority in unhealthy participant than healthy participant. It also seen reminders are in lower ranking for non-health problems compared to health problems.

2. Proposed Prototypes

For the experiment design, we decided to use Adobe XD to create a user interface for our mobile application design. Many buttons, slides and more gadgets were included in the software developments kits. The proposed prototype was designed based on a principle and evaluation list. Then the HTA of the proposed prototype has been displayed. Fig. 4 shows the hierarchical task analysis (HTA) that represents our Acua Water Quality checker application.

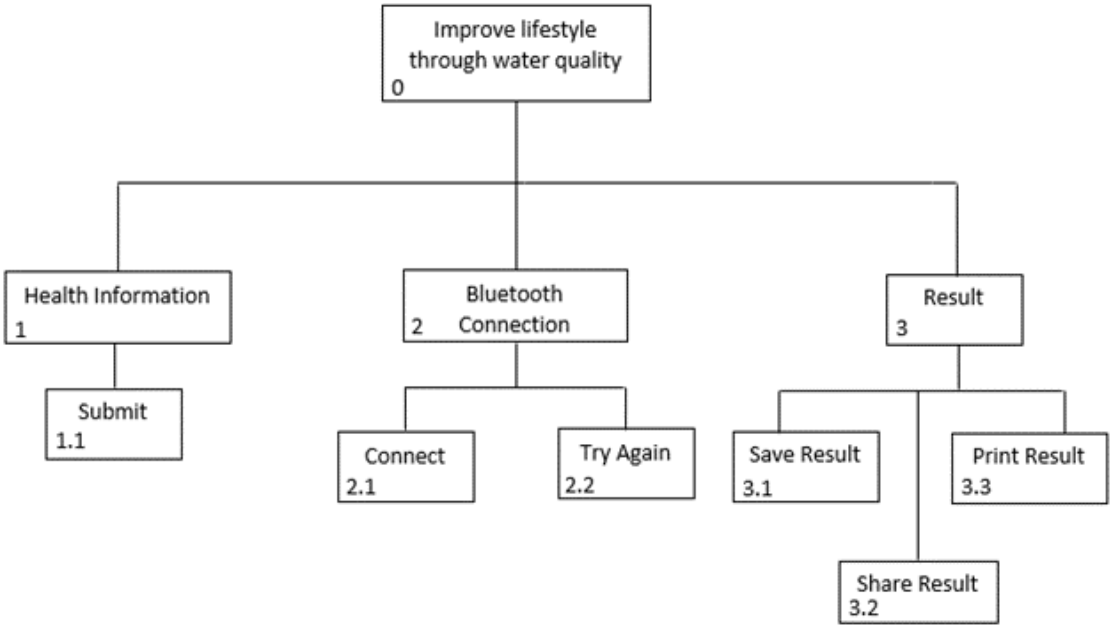

Figure 4. HTA based-on ACUA Checker Application

Task 1: Health Information

After entering the application, user is required to insert their health information in the space provided. Therefore, the first task is needed for the application detect and suggest the best water suits the user. The interface that is created is designed to be user-friendly and theoretically can be used even by an inexperienced user.

Task 2: Bluetooth Connection

User is required to connect their smartphone with the water detector via Bluetooth. This fulfil the second task as the user should connect the detector with their smartphone. The interface created are really user-friendly and easy to use. This makes it easier for any user regarding their experience with the technology.

Task 3: Result Display

Enables the users to read the result and suggestion given by the application. The application will suggest the suitable type of water to the user based on their medical condition. That is why the health information is important in this application. The result can be either print, save to the phone or share through social media such as Email, Facebook and others. It is shown that the experienced user needs a small amount of time to detect its functionality. Result display Oxygen Result, pH Result, Turbidity Results, Mineral Result, and Temperature Result.

Figure 5. Performing task 1

Figure 6. Performing task 2

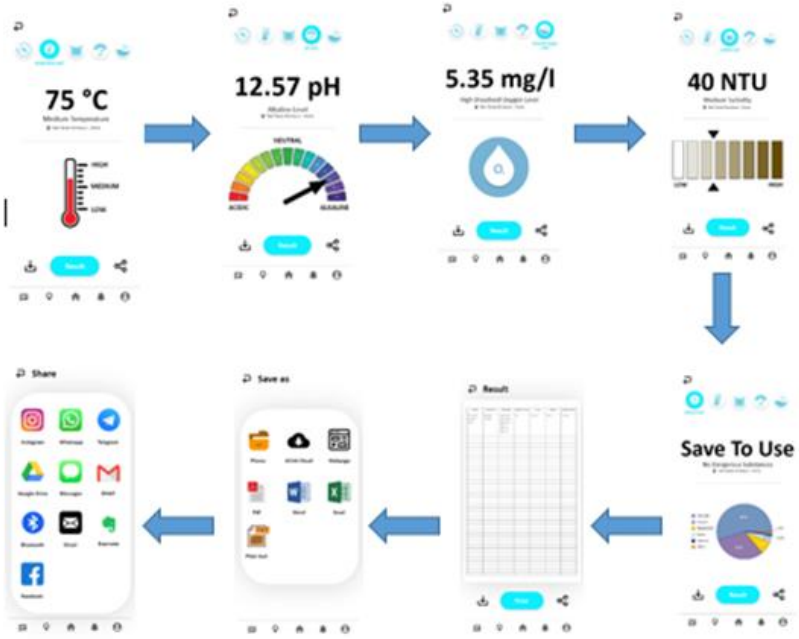

Figure 7. Performing task 3 steps

3. Usability Evaluation

Evaluation results were analysed to identify the usability of water quality detector mobile application between two user groups. All participants from both user groups managed to complete all tasks given. From the table above, for task 1, 2, and 3, the time users spend using application difference is not too big between two groups. All the data have been recorded in table the time users spend using the water quality detector mobile application (minutes) with the task given to two groups of participants (healthy participant and unhealthy participant) in range age of 21 to 60.

Type Of Participants	Amount Of Participants
Healthy Participants (HP)	7
Unhealthy Participants (UP)	5

Task	The Time Users Spend Using The Water Quality Detector Mobile Application (Minutes)											
	P1 (UP)	P2 (HP)	P3 (HP)	P4 (HP)	P5 (HP)	P6 (HP)	P7 (UP)	P8 (UP)	P9 (HP)	P10 (HP)	P11 (UP)	P12 (UP)
Health Information : Users key in all information provided about users health (e.g. Water Intake, Allergies, etc.)	5	2	1.5	3	2	1.5	4	5	1	1	4	5
Device Connection : Connect water quality detector with user's smartphone.	2	0.8	1	0.9	1.3	1.2	2.5	2	1.1	1	2	3
Data Results : Display chosen data (e.g. Temperature Level, Turbidity Level, etc.) that selected by users.	15	10	11	9	10	12	16	14	11	8	16	16
TOTAL OF TIME USING THE APPLICATION	22	12.8	13.5	12.9	13.3	14.7	22.5	21	13.1	10	22	24

Table 3. Result of the time users spend using the water quality detector mobile application.

The mean difference between healthy participants and unhealthy participants approximately 9 minute and 40 second apart. To compare with task 1, 2 and 3 the value may be seemed big but its logic to compare the participant in two group of healthy participants and unhealthy participants in age of golden age participants and young age participants. Therefore, water quality detector mobile application is proven achieve its conclusion show that healthy participants is faster using the application rather than unhealthy participants.

Group Statistics					
	Group	N	Mean	Std. Deviation	Std. Error Mean
Time_ Taken	Healthy Participants	7	12.9000	1.42712	.53940
	Unhealthy Participants	5	22.3000	1.09545	.48990

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Time_ Taken	Equal variances assumed	.031	.865	-12.305	10	.000	-9.40000	.76390	-11.10207	-7.69793
	Equal variances not assumed			-12.900	9.889	.000	-9.40000	.72866	-11.02605	-7.77395

Table 4. Result of T-Test

From the table 4, it is shown that healthy participant overall time taken to complete all tasks is bigger (SD: 1.42712), compared unhealthy participant (SD: 1.09545). This proves that, in using water quality detector mobile application, unhealthy participants in the golden age using the application takes time more than healthy participants that majority in the young age and good in using smartphone and applications. The first section of the Independent Samples Test output box given show the results of Levene's test for equality of variances. This tests whether the variance of scores for the two groups (healthy participants and unhealthy participants) is the same. The Sig. value tells that in the table significant value is 0.865 which refers to equal variances assumed. Levene's test in this table prove that the variances for the two groups (healthy participants and unhealthy participants) are the same. To find out whether there is a significant difference between your two groups, refer to the column labelled Sig. (2-tailed), which appears under the section labelled t-test for equality of means. Two values are given, one for equal variance and the other for unequal variance. In the two given for equal variance and unequal variance both have same value (Sig. - 2 Tailed: 0.000) means there is not significant difference in the mean scores on dependent variable for each of the two groups.

Impact size statistics give an indication of the magnitude of the difference between groups (not just whether that difference can be made by opportunities). There are several statistics of different effect sizes, most commonly used to be a square. Square equity can range from 0 to 1 and represent variance proportionality in the dependent variable described by independent variable (group). However, it can be calculated using the information provided in the output. Eta squared should be use as the formula (t2 / t2 + (Healthy Participants + Unhealthy Participant – 2)). Replacing with the appropriate values from the table (Eta squared =-12.305 / -12.305 + (7+ 4 – 2)). So, the eta squared is 3.723. The results of the analysis could be presented as an independent-samples t-test was conducted to compare the time users spend using the water quality detector mobile application (minutes) with the task given for healthy participants and unhealthy participants. There was no significant difference in scores for healthy participants (M=12.900, SD=1.42712) and unhealthy participants (M=22.300, SD=1.09545. The magnitude of the differences in the means was very big (eta squared=3.723).

DISCUSSION

Based on the result of time users spending on using the water quality detector mobile application in Table 1. The second task is the fastest task completed compared to the other tasks with a maximum of only 3 minutes for a participant to complete the task. This is because this task does not require much typing. For the first task, there is a lot of typing to be done on the app as it requires users to enter information about their health such as user weight, user height, allergies, water intake and so on. This task only requires the user to connect the application with a water quality detector via Bluetooth. It doesn't take long because there is no data that the application needs to receive. As for the third task, the

application displays the data received through the connected detector. So, it takes longer time than the second task because the application takes time to receive the data it has extracted. In the third task, the application divides the display of the received data into several sections (Water temperature, water pH, water content, water turbidity) according to user preferences. So, users spend longer on this task than on the second task because users will see every part of the user's choice

In the first task, unhealthy participants took longer to complete the task than healthy participants. The longest time taken by unhealthy participants to complete the first task was five minutes while the healthy participants took three minutes. This is because usually unhealthy participants do not know about their health. They don't care about their weight, their height, their height, and so on. If they know the information about their health, they only know their old information. For healthy participants, they don't have to worry about their information because they care about their health. So, it's easy for them to fill in information about their health.

Different situations for the second task, the results cannot be categorized according to the health of the participants. This is because it is tested based on the speed of a smartphone to connect the application with a water quality detector. The average time taken by the participants to complete this task was three minutes while the shortest time was taken by the participants was 0.8 minutes. This is because some participants have smartphones with sophisticated specifications that increase the speed of the phone. This makes the connection process between applications and water quality sensors faster. In addition, the telco coverage used by the participants also affected the speed of the connection.

For the third task, unhealthy participants took longer time to see content displayed by the application than healthy participants. This is because when the application displays the results of the data received, there is a recommendation given to the user regarding the amount of water taken and the type of water that is recommended for the participants to drink. For participants with many health problems, there should be many recommendations given by the app to make the participants healthier. In different situations, the amount of data selected by the participant may affect the time a user completes this task. There are some participants who select all four sections to be displayed by the application while other participants select only part of the data from the section provided to display on the application.

CONCLUSION

The main purpose of this paper has been to examine the usability for water quality checker mobile application “Acua Checker”. The results show that users take a lot of time in data results where the results will display based on the users choices. However, the users agree that the system is very easy to use and complex. They also found that the system is easy to learn especially for new user that never used this type of application before. The reported usability testing shows that healthy user learn the application a lot

faster compare to unhealthy user based on the task.

This probably caused by the age and exposure of application in these days. Most of the unhealthy user are older than healthy user. Finally, the data need to be insert in the health information also may be one of the reasons why unhealthy user took more time. All of the above features that represent our proposed prototype can be useful in implementing Acua Water Checker application.

FUTURE WORK

For future work we want to focus on the improvement of the system according to the user's opinion as the user's opinion is very important for the betterment of the system. We also hope that this app is expanding worldwide by entering the App Store for Apple and Play store for Google so that users worldwide can use the app. As for some people, they take it lightly for the cleanliness and quality of water. With this application, it can be consciousness to people around the world to be more careful about using quality and clean water in their daily lives.

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