Usability and desirability of OpenXdata – an electronic data capture tool for data collection in health research

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ABSTRACT

The conventional way of collecting data is based on ‘pen and paper’ which is still widely used. The use of electronic tools for data collection in health research is, however, increasing and there has been a shift in electronic data collection tools from proprietary to open-source softwares. OpenXdata is an open-source tool that supports both web and mobile phone based data collection. OpenXdata offers three main blocks of functions: forms design even complex forms, data collection and management. OpenXdata has been used in several health studies, but its user-friendliness has not been studied. This study aims to explore the usability and desirability of OpenXdata for the field data collection in health research. This study followed a mixed quantitative-qualitative approach through a System Usability Scale (SUS) survey and desirability study using Microsoft Product Reaction Cards. A total of 12 participants enrolled in either Master or PhD degree programme at the Centre of International Health, University of Bergen were recruited for this study. In this study, OpenXdata obtained a SUS score of 73.54 suggesting that OpenXdata can be well accepted in health research. The factors like ease of access and use, understandability, less time consuming and speed of data entry into electronic format are the main elements selected by the participants regarding OpenXdata. The findings from this study further indicate that OpenXdata can be a viable alternative to conventional data collection tools.

Keywords: *electronic data collection, Microsoft Product Reaction Cards, mobile data collection, open-source, OpenXdata, System Usability Scale (SUS).*

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ABBREVIATIONS

CI	Confidence Interval
CIH	Centre for International Health
CSV	Comma-separated value
DOTS	Directly Observed Treatment Short-Course for tuberculosis
EDC	Electronic Data Capture
EPI	Expanded Programme on Immunization
GB	Gigabyte
GIS	Geographical Information System
GP	General Practitioner
GPS	Geographical Positioning System
ICT	Information and Communication Technology
IRD	Interactive Research and Development, Karachi, Pakistan
MB	Megabyte
MDC	Mobile Data Collection
MDR-TB	Multidrug-Resistant Tuberculosis
MNCH	Maternal, Neonatal and Child Health
PDA	Personal Digital Assistant
PIs	Principal Investigator
PNMR	Perinatal Mortality Rate
OS	Operating System
RAM	Random Access Memory
SUS	System Usability Scale
UiB	University of Bergen
vs.	Versus
WRA	Women of Reproductive Age

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CHAPTER 1: INTRODUCTION

1.1. Background

1.1.1. 'Pen and paper' vs. 'electronic' data collection

Research data is the heart of any research work, so also in health research. Researchers spend a lot of time on deciding on methods for data collection which may be a challenging task [1] in order to ensure that the data are complete, error free and valid. Hence the data collection tool needs to be easy to use, reliable, cost-effective and friendly to the data collectors, research supervisors and Principal Investigators (PIs) [2].

The conventional way of data collection has been 'pen and paper' also referred to as questionnaires or paper forms, which is still widely used. The advantages of this method is its apparent simplicity and minimal requirement of resources including initial cost for implementation, technical proficiency, support, equipment and training [1, 2]. However, the use of paper forms for large studies might end up with large piles of paper and require large space for storage and transport. In addition, the amount of time required to enter the data from paper forms into electronic format and cross-checking to ensure the data entered are complete and accurate before analysis may be considerable [3].

The advancement in Information and Communication Technology (ICT) has provided new opportunities where researchers can use electronic tools such as web forms, handheld computers, tablets and mobile phones to collect data and directly transfer those data into the electronic format making them ready to be analyzed without requiring additional time for cross-checking the accuracy of data. The advantages of electronic tools may include improvements in all of the following: questionnaire development and formatting, data quality,

data collection, consistency, data accuracy, user preferences, data reliability, cost, timeliness of data capture and adherence to protocols for data collection [4-6]. The use of electronic tools for data collection may be beneficial for multi-center studies [1], in which data collection can be constantly performed without any delay in time or geographical barriers [2].

A study from sub-Saharan Africa [7] indicates that the initial cost for setting up an electronic data collection tool would be higher than for paper based data entry, however the requirement of fewer data entry clerks and computers may balance the higher initial cost. In this particular study around 25% of the total cost required for paper based data collection was saved by using electronic tools.

1.1.2. Electronic Data Capture (EDC) in health research

Paper based data collection is still prevalent in health research, but the use of electronic tools for data collection is increasing. A review by Lane *et al.* [4] has identified several clinical settings where EDC tool has been used. These settings include studies related to analgesic headache treatment, brain injury, pain, bipolar disorders, asthma, respiratory care, tobacco use, smoking cessation, orthopedic treatment, urinary incontinence, menstrual symptoms, diabetes, eating disorders, adolescent anxiety, HIV and blood donor studies.

Handheld computers like personal digital assistant (PDA) have been in use in clinical trials for several years [2, 8, 9]. The use of mobile phones and tablet computers are increasing in public health research [10] as a cost-effective method to collect prospective health data for disease surveillance [11]. As these tools become more and more common, the need for training of users (end-users) may decrease [7].

1.2. OpenXdata – an open-source mobile data collection (MDC) tool

OpenXdata[1] is an *open-source* web and mobile phone based data collection tool. The open source nature of this tool refers to two things: 1) the software is free to use without any charges and 2) the source code can be accessed by the general public for use, modification and integration with other software as desired. The OpenXdata consortium comprises many organizations globally with deployments (= functional installations of OpenXdata) in Africa, South Asia and South America.

OpenXdata has three main blocks of functions i.e. *'design'*, *'collect'* and *'manage'*. Researchers can design electronic forms, use the forms to collect data via mobile phone or web browser as well as create multiple users and assign specific roles and study permissions to each of them. The data can be uploaded directly to an electronic database and thus can be exported as a comma-separated value (CSV) format for analysis in any standard statistics software. A prominent feature of OpenXdata is that it functions on low-cost mobile phones as long as they are Java enabled mobile phones.

1.2.1. Requirements and installation

There are two additional open-source softwares required to deploy and run OpenXdata: Apache Tomcat[2] and MySQL[3]. Apache Tomcat is a web application server software that is used to run the OpenXdata web application (developed in Java) whereas MySQL is a database management system. The OpenXdata server and mobile application (mForms) can be downloaded from http://www.openxdata.org/download/. The detailed procedure to install the pre-requisites, create databases, and deploy OpenXdata server has been documented on

[1] Website: www.openxdata.org
[2] Website: http://tomcat.apache.org/
[3] Website: http://www.mysql.com/

http://doc.openxdata.org/. The minimum hardware requirements for OpenXdata are 4 GB hard disk drive with at least 1 GB of free space, and 384 MB RAM. The mobile phones must be Java enabled in order to run the mForms.

1.2.2. From 'form design' to 'management'

i. Design

In OpenXdata all information is collected in the form of 'studies'. A study may contain one or several questionnaires or forms. A form may contain one or several pages and each page may contain one or several questions (Figure 1). These need to be created in hierarchical order from top to bottom, first a study, and then a form, etc. OpenXdata has a versioning functionality which means that various versions of a single form can be made. Once a new version of an existing form is created, the older version is hidden; however all the versions can be made visible if required.

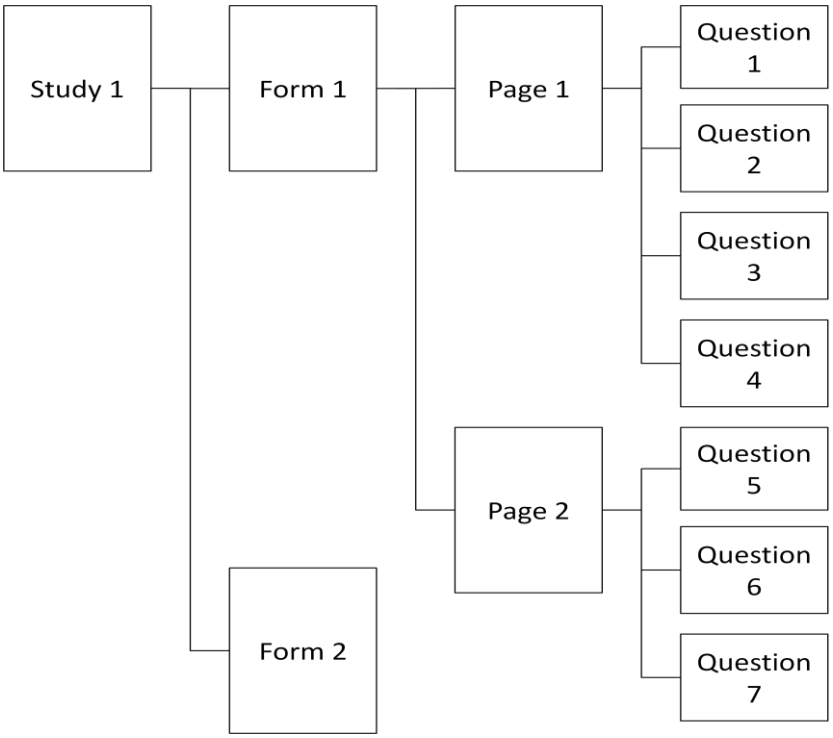

Figure 1: Hierarchy of form design in OpenXdata

[4]

In OpenXdata, one can design complex forms in a graphical design interface as shown in Figure 2. The design interface allows the user to enter the questions text, help text (optional), choose question type and assign a variable name, the so called ‘binding’ for the question. The question types supported by OpenXdata are text, number, decimal, date, time, boolean, single select, multiple select, repeat, audio, video, picture, single select dynamic, GPS and barcode. The binding name is either a variable name assigned for each question or a pre-defined value assigned for answer options in case of single select and multiple select questions. While exporting the data set, the column header will be named after the binding representing the question. The binding must be unique for each question within a form and should not contain any special characters except ‘_’ (underscore). However, the binding for the answer options can be same for several questions.

In addition, the design interface also allows the user to choose whether a question is to be made ‘visible’, ‘enabled’, ‘locked’ or ‘required’; to assign default value for the questions; and to set skip logic and validation logic. The skip logic helps to skip or enable one or more questions based on one or more conditions selected. The validation logic helps to validate and prevent errors that might occur during data collection such as entering wrong numerical values, date or length of data to be entered. The validation criteria can also be set to validate the length of repeat questions to be answered. A pre-defined error message will be shown if the data entered does not meet the validation criteria. The validation check ensures that the data are appropriate and thus maintains data quality from the very beginning of the study. The design interface also facilitates editing of the design surface and preview of the web form.

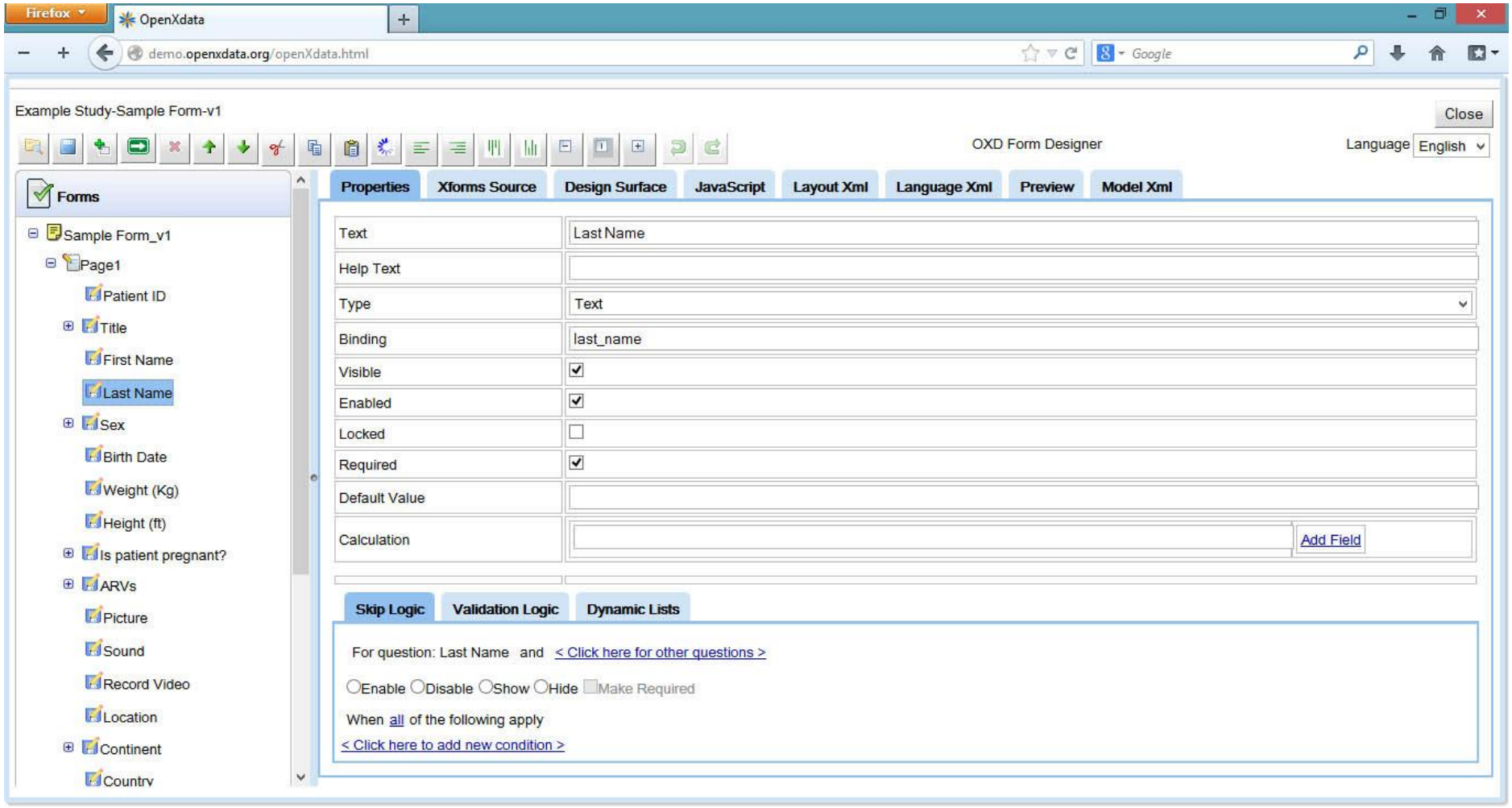

Figure 2: Graphical design interface of OpenXdata

[6]

ii. Collect

OpenXdata provides two platforms for data collection. One is the use of a web browser in desktop or laptop computers or smart-phones with web browser and the other is via 'non-smart' mobile phones. The appearance of web form can be modified and designed as required to give it a good look like in a paper form (Figure 3). The data collection using web forms can be done either using a single computer to install OpenXdata and collect data locally, or installing OpenXdata on an external server and using multiple computers to collect data. The later method of collecting data using multiple computers require internet connection to communicate with the server throughout the data collection session, however it is not necessary to install OpenXdata on the computers used for data collection. Once the data collection is complete, the form can be send by clicking on 'Submit' button. The confirmation of successful data submission will appear immediately along with an auto-generated session reference which is a unique identifier for the data collected.

The second method for data collection is using non-smart mobile phones. The mobile phones must be Java enabled and able to run Java applications. The mForms application (which functions like an 'app' on a smart-phone) must be installed to collect data via mobile phones. For the first time use, the mForms requires synchronization with the server which checks the authentication of the data collector and then proceeds to download studies and forms. Only published versions of the forms are available for data collection. Any additional 'apps', applications must also be installed on the phone, for example if the forms contains Barcode questions, a barcode application must be installed, for photo or video, a camera app must be installed.

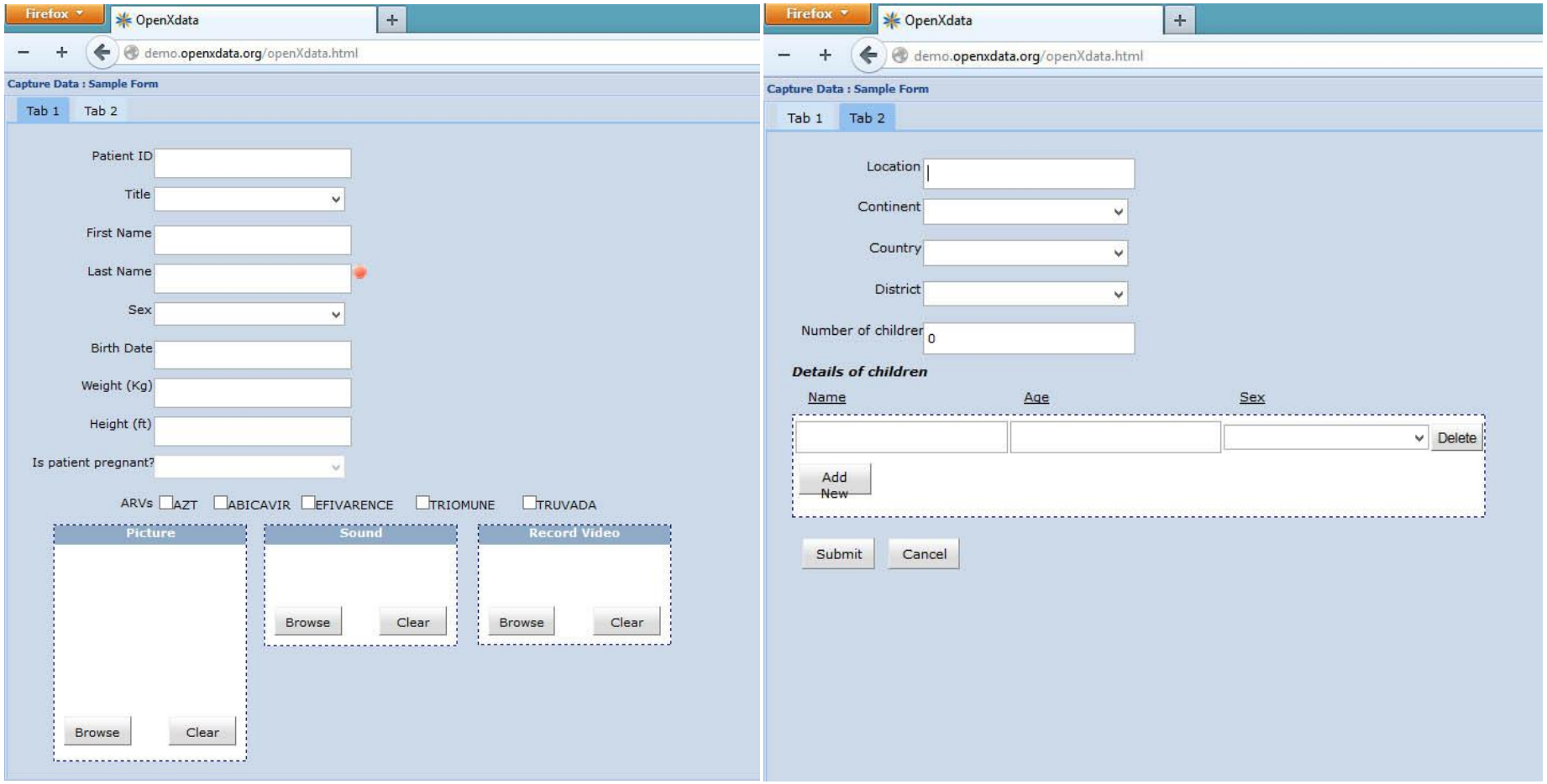

Figure 3: Snapshots of an example web form

Once the form is downloaded, it is ready to collect the data. A unique feature of collecting data via mobile phones is that it does not require network availability or internet connection throughout the data collection session, except during 1) first time authentication, 2) study and form download and 3) data upload. This means that the data can be collected even in the rural areas in low-income countries where telecommunication infrastructures are poor or sometimes not available and later uploaded to the OpenXdata server once the data collector comes within the network range.

Figure 4: Snapshot of an example form in the mForms app on a Java emulator

Another feature of using mForms is that the data can be saved without uploading even if it is incomplete and it can be completed afterwards, which is not possible for web forms. The form on the mobile phone appears as simple text with an automated formatting (Figure 4) unlike the web forms where it is possible to make a layout in the designer to customize the appearance. The questions designed as 'required' (= must be filled in order to complete the

data collection) appear with a red dot in front in the web form and with an asterisk (*) in the mForms app.

iii. Manage

In addition to form designing and data collection, OpenXdata also provides management functionality both in order to manage users as well as data. The administrator (by default) has the permission to create users with their specific user name and password as well as to assign specific roles to the users. The user roles defined in OpenXdata with their default permissions are presented in Table 1.

Table 1: User Roles and Permissions in OpenXdata

Role	Description	Default Permission
Administrator	The super user of the system	• Adding, editing, viewing and deleting- Studies, Users, Role, Tasks, Settings, Forms, Form data, Locales, Permissions • Scheduling and adding Parameter • Exporting and importing Studies • Dashboard, editing Role Permissions and My Users • Listing, editing and importing users • Editing My Form data • Viewing and processing Unprocessed Data • Monitoring and editing Form Data Row
Study Manager	Responsible to create studies and design forms	• Adding, editing, viewing and deleting - Studies, Forms • Exporting and importing Studies • Dashboard and editing My Users
Data Manager	Responsible to view and edit collected data	• Viewing and editing Form data • Viewing Studies and Forms • Dashboard • Listing Users and editing My Users
Data Collector	Responsible to collect data web form	• Adding Form data • Viewing Studies and Forms • Dashboard and editing My Users
Mobile User	Responsible to collect data via mForms	• Adding Form data • Viewing Studies and Forms • Editing and viewing My Form data

The administrator can add or remove any of these permissions from the specific user upon requirement. As mentioned above, the administrator has the permission to manage collected data, export data from OpenXdata and manage the unprocessed data.

1.2.3. Current use of OpenXdata in health research

OpenXdata has been used in rural Uganda (Busujju County of Mityana District) as a data collection tool in a project to improve maternal, neonatal and child health (MNCH) [12]. In the study, questionnaires for basic health information, nutrition, infectious disease, MNHC indicators and family planning options were developed using OpenXdata. The study participants were divided in 6 groups, namely newborns, children < 5, women of reproductive age (WRA), children > 5, husbands/partners and women over 50. The data was collected using mobile phones from 5500 residents that include 1600 WRA and 1100 children < 5. The impression from the study was that OpenXdata was very efficient in community settings with limited access to health services.

A study in rural Burkina Faso to measure the perinatal mortality rate (PNMR) used PDA with questionnaires designed in OpenXdata [13]. Mobile phone based data collection using OpenXdata has also been conducted in a community-based cross-sectional study in Kampala Uganda to examine timeliness of the recommended Expanded Programme on Immunization (EPI) vaccines [14]. A study in Karachi, Pakistan for accessing women and general practitioners (GPs) attitude towards breast cancer, mammographic screening and local barriers to breast health care had also used OpenXdata mobile application to collect data [15].

The Interactive Research and Development (IRD[4]), a Pakistan-based organization has integrated the mobile application of OpenXdata with OpenMRS[5], an open-source medical

[4]Website: http://irdresearch.org/

record system to collect Directly Observed Treatment Short-Course (DOTS) information for multidrug-resistant tuberculosis (MDR-TB) patients [16]. The DOTS information can be directly entered on mobile phone and transferred to the patient's medical record developed in OpenMRS. This system allows effective monitoring of DOTS. Furthermore, IRD has also developed a geographical information system (GIS) module for real-time visualization of patient's information in Google Earth [17].

A two year long phone based screening for dog-bites and rabies using OpenXdata server and mobile applications conducted in Pakistan has suggested that real-time data capture using OpenXdata will be beneficial to setup disease surveillance systems in developing countries at a low-cost [11]. Moreover, EpiHandy[6] the predecessor of OpenXdata mobile data collection tool has been used for field data collection in several health studies [18-23].

1.3. Rationale of the study

Since OpenXdata is free and open-source software, it is difficult to identify how many studies have used it for data collection. There are several published research articles and reports regarding the use of OpenXdata for field data collection in health research. However, these published studies do not provide sufficient information about usability and user-friendliness of OpenXdata. Therefore, this study aims to explore the usability and desirability of OpenXdata for the field data collection in health research.

[5] Website: http://openmrs.org/
[6] Website: http://epihandy.org

1.4. Research objectives

1.4.1. General objective

The general objective of this study is to explore the usability and desirability of OpenXdata in health research.

1.4.2. Specific objectives

The specific objectives of this study are as follows:

i. To evaluate the user-friendliness of OpenXdata in health research.
ii. To explore the desirability factors that might influence the use of OpenXdata in health research.
iii. To understand the perceptions of the health researchers regarding their interests, experiences and expectations on OpenXdata in comparison to the paper based data collection method.

CHAPTER 2: METHODOLOGY

2.1. Study design

This study followed a mixed quantitative-qualitative approach to meet the objectives. The quantitative part was assessed through System Usability Scale (SUS) survey, whereas the qualitative part was evaluated by using Microsoft Product Reaction Cards followed by a short group discussion to understand the participants' perspectives on their experience and suggestions with regards to OpenXdata.

2.1.1. The System Usability Scale (SUS) survey

The System Usability Scale (SUS) survey was developed by John Brooke as a quick method to assess system usability [24]. It consists of 10 statements based on a Likert scale to capture the subjective assessments of usability. The statements are scored on a 5-point scale ranging from 'Strongly disagree' to 'Strongly agree' as shown in Figure 5.

The odd numbered statements are worded positively whereas the even numbered statements are worded negatively. The SUS should be used after the respondent gets an opportunity to use the system under evaluation, but before any debriefing or discussion is done. The respondents should also be informed to provide immediate response for each statement, instead of thinking for a long time [24]. The center point of the scale i.e. 3 should be marked if the respondent is not able to answer particular statement. The SUS survey results in a single number score ranging from 0 to 100 that measures the overall usability of the system. The average SUS score above 70 suggests that the system is acceptable whereas the score below 70 suggests that the system needs some improvements to get accepted by the users [25].

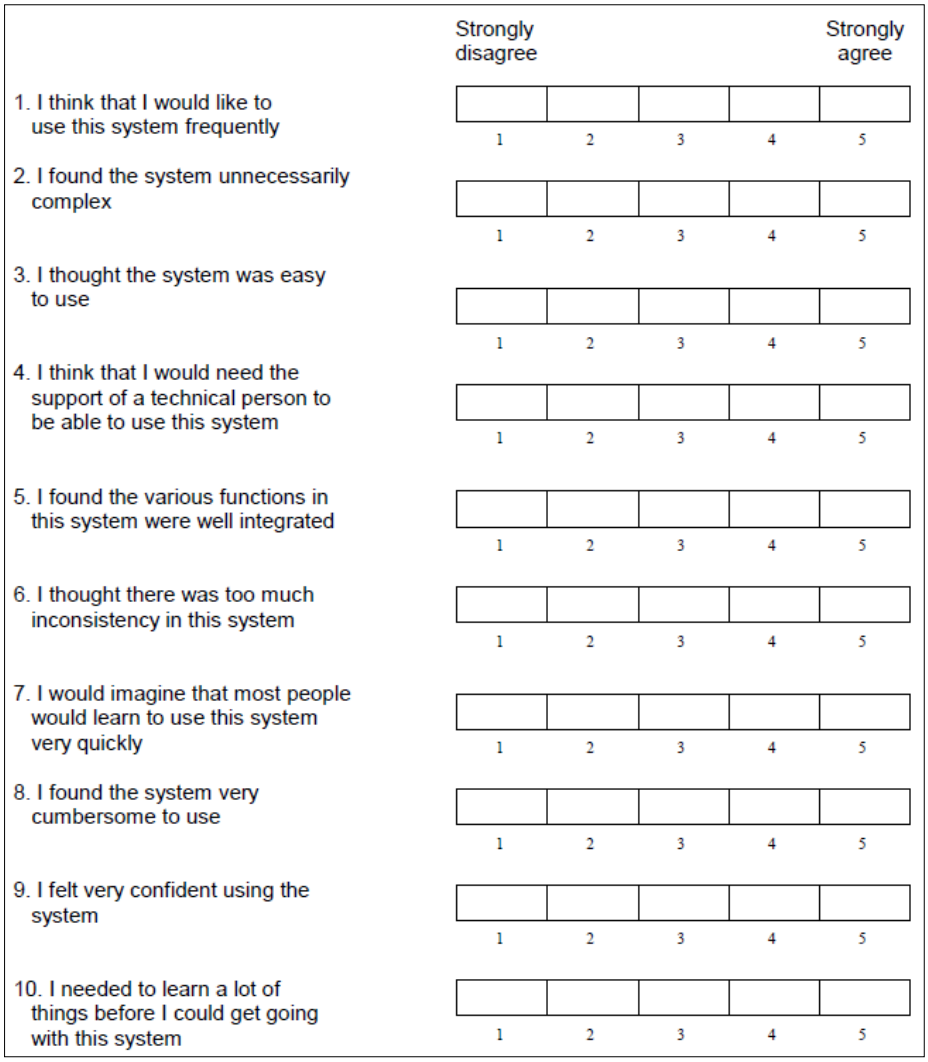

Figure 5: SUS Statements

A study conducted to compare different questionnaires used for system usability shows that the SUS has the ability to determine 100% correct conclusions at a small sample size of 12 participants [26], suggesting that it is an appropriate tool to evaluate the usability of the system even in small studies. Furthermore, it is highly effective because it is cost-effective, quick and easy to be used by participants and administrators as well as flexible enough to assess wide range of interface technologies [25, 27].

2.1.2. Measuring desirability using Product Reaction Cards

Table 2: 118 Product Reaction Cards[7]

Accessible	Creative	Fast	Meaningful	Slow
Advanced	Customizable	Flexible	Motivating	Sophisticated
Annoying	Cutting edge	Fragile	Not Secure	Stable
Appealing	Dated	Fresh	Not Valuable	Sterile
Approachable	Desirable	Friendly	Novel	Stimulating
Attractive	Difficult	Frustrating	Old	Straight Forward
Boring	Disconnected	Fun	Optimistic	Stressful
Business-like	Disruptive	Gets in the way	Ordinary	Time-consuming
Busy	Distracting	Hard to Use	Organized	Time-Saving
Calm	Dull	Helpful	Overbearing	Too Technical
Clean	Easy to use	High quality	Overwhelming	Trustworthy
Clear	Effective	Impersonal	Patronizing	Unapproachable
Collaborative	Efficient	Impressive	Personal	Unattractive
Comfortable	Effortless	Incomprehensible	Poor quality	Uncontrollable
Compatible	Empowering	Inconsistent	Powerful	Unconventional
Compelling	Energetic	Ineffective	Predictable	Understandable
Complex	Engaging	Innovative	Professional	Undesirable
Comprehensive	Entertaining	Inspiring	Relevant	Unpredictable
Confident	Enthusiastic	Integrated	Reliable	Unrefined
Confusing	Essential	Intimidating	Responsive	Usable
Connected	Exceptional	Intuitive	Rigid	Useful
Consistent	Exciting	Inviting	Satisfying	Valuable
Controllable	Expected	Irrelevant	Secure	
Convenient	Familiar	Low Maintenance	Simplistic	

[7] Developed by and © 2002 Microsoft Corporation. All rights reserved.

The usability survey tells us about the usefulness and user-friendliness of the ICT application, but it fails to measure intangible aspects of the user experience regarding their desire to use the application in their regular work. The 'desirability' assessment is qualitative in nature and using Likert scale to answer questions regarding desirability is often meaningless; whereas interviewing each and every participant can be time consuming and difficult to analyze in a short time. Both these methods to assess desirability can result in biased answers from the respondents since they tend to give positive ratings for the ICT tools and might fail to provide negative feedback. In order to overcome these barriers in desirability assessment, Microsoft Corporation has developed a quick and easy tool called 'Product Reaction Cards' to measure the desirability [28, 29].

The product reaction cards consist of a set of 118 words (Table 2) comprising of 60% positive and 40% negative or neutral words. Each of these words is printed individually on a card. A set of these 118 cards are then handed to the participants and asked to pick the cards that best describe the ICT tool or their feelings when they used it. The selected cards are then narrowed down to a set of 5 cards. The participants are then asked to provide reasons for the choice of the 5 best cards.

2.2. Data collection

The participants in this study were students enrolled in either Master or PhD degree programme at the Centre of International Health (CIH), University of Bergen (UiB). A total of 12 participants were recruited for this study. The participants were selected through open invitation via email or direct contact during class hours. The participants had no previous experience of working with OpenXdata, however some of them had heard about it. Therefore a training session of around 2 hours and 30 minutes was organized for the participants before

data collection. A total of 4 training and evaluation sessions were conducted on 25.04.2013 (5 participants), 06.06.2013 (3 participants), 26.06.2013 (1 participant) and 1.07.2013 (3 participants) depending upon the availability of the participants.

The training was divided into two parts. The first part comprised of introduction of OpenXdata to the participants. A PowerPoint presentation (Appendix A) was given which also included videos to provide an idea about form design and usage of OpenXdata in health research. In addition, a live demonstration of OpenXdata functionality such as creating new users, study design, form download and data upload via mForms and data exportation was also performed. The second part included a small workshop were participants were asked to design a simple survey form (Appendix B) and collect some data using web form and mForms. The participants were provided with their own user name and password and given a mobile phone each (Figure 6).

Figure 6: Mobile phones for data collection

After completing the training and workshop sessions, the participants were kindly requested to fill out the SUS survey form (Appendix C) which had been previously downloaded to the

provided mobile phones. Once the SUS survey completed, the participants were then provided with a printed list of Product Reaction Cards (Appendix D) and requested to pick as many words as they wanted that best suits their experience regarding OpenXdata and write them in a provided paper (Appendix E). For this study, a printed list of words was used instead of individual cards for each word. However, the words were placed randomly and not alphabetically. The purpose of randomizing the words in printed form was to make it similar to shuffling the individual cards. The participants were then asked to pick up top 5 cards among those they had previously selected and write them down in another paper form (Appendix F) along with the reason for choosing the word in one or two sentences.

After completing the desirability survey, a small group discussion was conducted focusing on the experiences, usefulness, drawbacks and problems faced by participant in order to know their first impression about OpenXdata and also to find out their interest on using it for their research work. The group discussion was recorded with due permission from the participants.

The whole session was organized to be around 3 hours 30 minutes and included OpenXdata training (1 hour), workshop (1 hour 30 minutes) and data collection (1 hour).

2.3. Data analysis

2.3.1. Calculation of SUS score

In order to compute the SUS score, the contributions for odd numbered statements were obtained by subtracting 1 from the respective scale position, whereas for the even numbered statements, contributions were obtained by subtracting the respective scale from 5, thereby resulting in a score contribution in the range of 0 to 4. All these contributions were then added and multiplied by 2.5 to get the single overall score for an individual participant [24]. The SUS score calculation was done in Microsoft Excel.

2.3.2. Demonstration of desirability factors

The words from the desirability study have been demonstrated as world cloud generated from Wordle[8]. The font size of the word in the word cloud signifies the frequency of repetition, i.e. the biggest word means it has been mentioned by most of the participants. The frequently repeated words were identified as the desirability factors for OpenXdata.

2.3.3. Interpreting the participants' perspectives

The recordings from the group discussion were transcribed word by word. The participants' interpretations of their experiences and suggestions were analyzed with an interpretive approach [30, 31]. Further interpretations of the participants' views were made and are presented accordingly with the quotations as expressed by them in the result section.

[8] http://www.wordle.net/

CHAPTER 3: RESULTS

3.1. User-friendliness of OpenXdata

The scores given to individual statement by 12 participants and the SUS analysis are presented in Appendix G and Appendix H respectively. The graph below (Figure 7) presents the individual SUS scores from the participants.

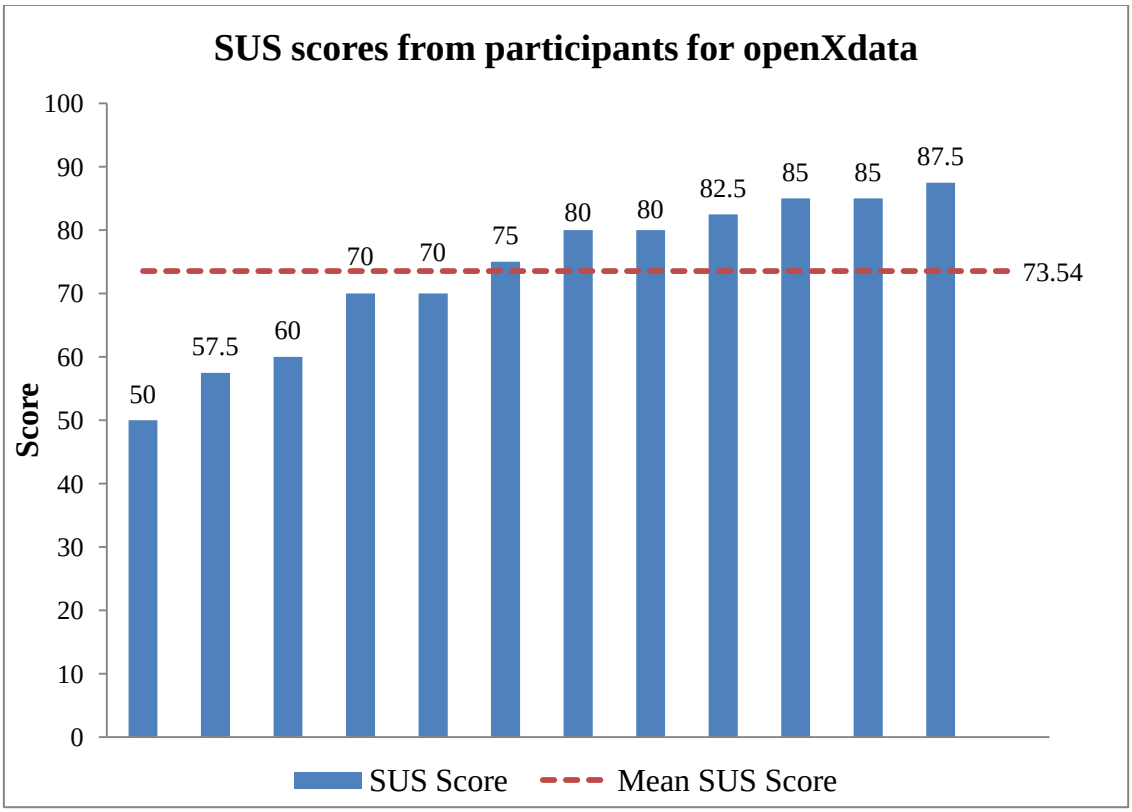

Figure 7: SUS scores from participants for OpenXdata

The lowest SUS score obtained for OpenXdata was 50 whereas the highest score was 87.5. The mean SUS score for OpenXdata (presented by dotted line in the graph) has been calculated to be 73.54 which suggest that OpenXdata is user-friendly and can be accepted for data collection in research.

3.2. Desirability of OpenXdata

From the initial desirability study as shown in Figure 8, it is clear that there were more positive responses than the negative or neutral ones. Out of 190 words selected by 12 participants 184 (97%) were positive (Appendix I). The positive words that were mentioned by most of the participants were *'accessible'*, *'organized'*, *'reliable'*, *'relevant'*, *'time-saving'*, *'understandable'*, *'useful'*, *'usable'* and *'trustworthy'*. The negative or neutral words mentioned by the participants were *'time-consuming'*, *'busy'*, *'engaging'*, *'not secure'* and *'unpredictable'*.

Figure 8: Word cloud for initial Product Reaction Card selection

When the participants were asked to narrow down their previous selection to 5 cards, only 2 words out of 60 were negative (Appendix J). One of the participants felt that OpenXdata is *'slow'* and mentioned that *"I used lot of the time entering the data into the mobile."* Another participant mentioned that OpenXdata is *'not secure'* since it depends on the internet connection. However, the word cloud in Figure 9 shows that the participants would choose

OpenXdata in their research work because it is *'time-saving'*, *'accessible'*, *'easy to use'*, *'understandable'* and *'fast'*. These words were mentioned by most of the participants. The reasons behind selecting these cards have been presented in Table 3.

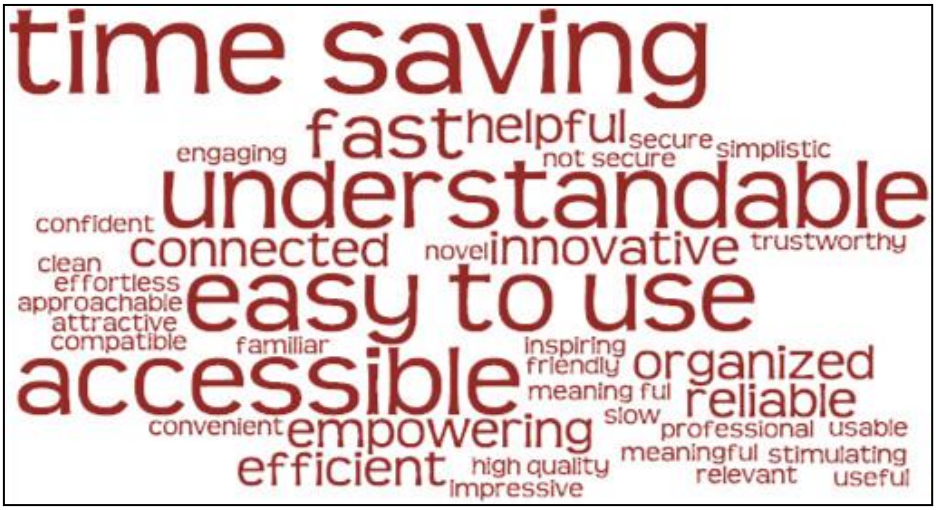

Figure 9: Word cloud for top 5 selected Product Reaction Card

Table 3: Reasons behind selection of top 5 Product Reaction Card

Product Reaction Card	Reasons for selecting the card
Time-saving	Data can be managed in a way that minimize errors during data entry; reduces lot of work after data collection such as data entry in electronic form and cross-checking in comparison with paperwork.
Accessible	Open access program; no need of hi-technology mobiles; applicable in rural areas or areas where network is not accessible; can be accessed from any part of the world.
Easy to use	No need of more technical knowledge or training or assistance from technical person; graphical interface makes form design simpler.
Understandable	Relatively easy to learn; easy to understand the questions, answers and how to enter data in the required fields for close-ended questionnaires.
Fast	Avoids hectic paperwork; can easily get used to (getting faster in entering data by each time use); forms and data can be uploaded and downloaded fast if the internet connection is strong via mobile.

3.3. Participants' first impression of OpenXdata

The participants pointed out in particular that OpenXdata may be time saving because data can be managed in a way that minimize errors during data entry and also lot of work after data collection such as entering data in electronic form as well as cross checking is reduced. One of the participants stated:

> *"It (OpenXdata) makes the analysis easier because the data is being labelled via bindings, skip logics from the designing phase itself, which is not possible in paper forms."*

The participants mentioned that the open-source nature of OpenXdata along with its functionality in low-cost mobile phones which are applicable in rural areas makes its widely accessible. They further thought that OpenXdata could be very useful in low-resource settings without the need of purchasing additional equipment since it can use hardware that is already there in many places. In addition, they considered OpenXdata to be easy to use since there will be no need of more technical knowledge or training to use basic functions of OpenXdata. However, some of the participants had an impression that motivating the data collectors and designing questionnaires can sometimes be time-consuming, even though data collection and storing data was perceived as easier with OpenXdata.

On the other hand, the participants have emphasized that by using OpenXdata it is easy to understand questions and enter data in required fields especially with structured close-ended questionnaires. The participants pointed-out that the graphical interface in OpenXdata has made forms design very simple. Further, they noted that the designer actually assisted them in organizing their plans for the analysis, one of the participants said:

"I think what I found interesting in entering questions was that I had to think about what is my data type and also logic and range. So, I was doing lot of things, not only making the form but also thinking forward, actually sort of labeling data from now on only. When designing questions in paper, I had never thought of these things and something that is very innovative and interesting to me."

Most of the participants experienced problems with 'Single Select Dynamic' question type and setting up 'Validation logic'. All the participants suggested that a longer session of training or a follow-up training after having some time to practice with OpenXdata will help them to understand and get used to with it. They agreed that a single training to data collectors is enough since most of the people nowadays are familiar with the use of mobile phones; however this varies from person to person, for instance generally younger people have acquired a higher user skills level of mobile phones and therefore may be more at ease than the older people. The participants further suggested that implementing OpenXdata immediately might be challenging, since it requires a certain amount of resources i.e. time, money and training to fieldworkers. A participant mentioned:

"It (OpenXdata) is quite good tool, but before implementing it you have to have good resources (money and time) and train the fieldworkers. Resource is quite important."

Another participant added:

"Before using it in the field, we have to think about budget, getting people aware of how to use it and everything. I find it very convenient, but there is lot of groundwork that needs to be done before you can actually start to practice."

CHAPTER 4: DISCUSSION

OpenXdata is an open-source electronic data capture tool that supports both web and low-cost non-smart-phones to collect data. In this study we evaluated the user-friendliness and desirability of OpenXdata for data collection in health research. The user-friendliness was evaluated using the SUS survey and the desirability factors influencing the use of OpenXdata in health research were identified through Microsoft Product Reaction Cards. The findings from the study suggest that OpenXdata can be a viable alternative to conventional 'pen and paper' data collection method in health research.

4.1. Reflections on the results of the study

In our study we obtained the SUS score of 73.54 for OpenXdata. The calculated SUS score is adjacent to the adjective rating 'OK' and the letter grade 'C' [25, 27]. This score was above the threshold for being 'user-friendly' and indicates that OpenXdata can be well-accepted in health research [25].

It was noted that there was a considerable variation in the score with some individual SUS scores as low as 50. There are several possible explanations for this. First, data entering difficulties were mentioned by one participant. Though no reason for this difficulty was mentioned by the participant, the possible reason for this can be the small screen size of mobile phones [5]. A second reason is that the user-friendliness of OpenXdata actually depends on how familiar the user is with computing and mobile devices. The third reason for some low scores may be that we, in fact, assessed the usability of several user roles in OpenXdata simultaneously, as our participants were introduced to tasks with different level of complexity in one single session: starting with the easy tasks such as data collection on the

phone moving on to the next level with forms design and the most complex level which was the design of skip patterns and validation patterns. It is obvious that for the more complex tasks, the participants did not get enough time to fully understand the software and it seems that some of the participants were 'scared off' from the software and gave it a low score because of this. In a repeat study of usability, it will be important to have the participants to score the software based on roles they have had a chance to become acquainted with. For instance, let participants do data entry only and then score the software.

That several participants scored the software highly, was further justified by the desirability study in which 97% of the words were in favor of OpenXdata indicating that the participants were positive to the use of OpenXdata for data collection in health research. The participants found OpenXdata to be *'time-saving'*, *'accessible'*, *'easy to use'*, *'understandable'* and *'fast'* that qualitatively explain the reasons behind user-friendliness of OpenXdata. These reasons reveal that OpenXdata has advantages similar to paper forms like simplicity, accessibility and minimal requirement of support and technical proficiency [1, 2] as well as reduces piles of paper works, maintain the quality of data and ease the data analysis process [3].

The OpenXdata has good impression among study participants because of its open-source nature, graphical interface for form design and its functionality in low-cost mobile phones indicating that OpenXdata can be a promising alternative to the conventional data collection method. The use of mobile phones as a communication media is increasing day by day; implying that users are familiar with this technology. Therefore, mobile data collection using OpenXdata could require less training to get accustomed with OpenXdata [7].

4.2. Reflections on the methodology of the study

The SUS study is said to be a quick tool to assess the usability of EDC tools [24, 26]. Because of this reason, SUS was included in the study design as usability evaluation tool among others. In addition, the desirability study with the use of Microsoft Product Reaction cards was included as a qualitative tool to assess the intangible aspects of users' experience which usability study alone would not provide [28, 29]. The use of Microsoft Product Reaction cards has advantages over qualitative interviews as it is less-time consuming both for the interviewee and the interviewer, easy analysis and tendency to report both positive and negative aspects of the tool under evaluation.

However, this study had several methodological limitations that may have influenced the result. One of the limitations is the sample size of this study. An email was sent to the students at CIH to inform about the training and evaluation session and to ask for their appropriate time they can manage to come to training. However, only two participants replied to the email and therefore more participants were approached by direct contact during class hours. Only 12 students agreed to participate in this study.

It is obvious that with a larger number of participants of the study would have increased the reliability and for the Microsoft Product Reaction cards study a minimum of 14 participants are required in order to present correct conclusions about the EDC tool under evaluation [26]. Thus, the results of desirability evaluation of OpenXdata in this study may not be precise.

Another limitation is the way in which SUS evaluation was conducted. Ideally, the evaluation should have been conducted among users that have been using or had previously used OpenXdata in their research. However, such participants were unavailable locally in Bergen.

In our Plan B, we involved young students with a general interest in health research in low-income countries. A SUS evaluation of OpenXdata from these participants before the training would not be meaningful and therefore a short training was given. Ideally, a SUS evaluation is supposed to be done after the participants have had an opportunity to use the system and before any debriefing was conducted [24]. This condition was not fulfilled in this study.

The usability and desirability evaluation of OpenXdata in a real health study would present appropriate result with regards to the respective research setting, type of study and data collectors' technical skills. It is obvious that large studies involve research supervisors, PIs and data collectors with varying educational and technical background. This varying level of knowledge and difference in study type and setting may have impact on the usability and desirability of OpenXdata. It has been suggested that the evaluation of EDC tools depends on the form design, end users and their working environment [32]. In contrast, the participants in this study were students and it was assumed that they have satisfactory technical expertise. No information about their computing knowledge was assessed as it was not the part of the study design. So, the association between level of computing knowledge and the user-friendliness of OpenXdata could not be evaluated. Also, the training and evaluation was done in a close-setting with limited training and workshop sessions. The sample questionnaire provided in the workshop was simply a collection of all the question types offered by OpenXdata, which in real study may differ in case of number of questions, type and complexity. Thus the results from this study may not resemble other research settings.

Furthermore, both the training and evaluation was conducted on the same day. The participants evaluated OpenXdata based on what they learned during the training session and the short practice they had. In the training session, the features of OpenXdata were highlighted which might be the reason behind the highly positive responses during desirability

evaluation in comparison to the result from SUS survey which mainly focuses on the practical use of the system such as user-friendliness and ease of use that highly depend on how frequently the participants has been using or had used the system. If the participants were provided with some more time to be familiar with OpenXdata then more accurate result could possibly be obtained. It would have been appropriate to have the evaluation in two phases: the first one immediately after the training and workshop sessions and the second after an interval of few days with an expectation that the participants would practice themselves to be familiar with OpenXdata.

In addition, the evaluation was focused on overall OpenXdata tool. The OpenXdata provides data collection platform both using web form and mobile phone. Also, it provides functionalities in form design and management. The usability and desirability evaluation of each of these functionalities rather than as an overall evaluation would help to identify the good qualities as well as shortcomings of OpenXdata that would provide guidance for the system developers for further improvements of the system.

Another limitation of this study is that the evaluation was focused on OpenXdata only and no comparison with the paper based data collection was conducted. A comparative study would help to identify key differences between these two data collection methods regarding data collection time, data quality, field staff and training requirements, ease of use, user satisfaction and cost requirement, thereby strengthening the results of the study. The comparative study of such kind has been suggested to be free of publication bias and subject selection bias [4] .

CHAPTER 5: CONCLUSION

According to this study, OpenXdata can be well accepted for field data collection in research. The factors like ease of access and use, understandability, less time consuming and speed of data entry into electronic format are the main reasons among others behind the user-friendliness of OpenXdata. The use of low-cost non-smart mobile phones to collect data even in the areas where mobile network is unavailable and use of graphical interface to design complex questionnaires and code the data from the very beginning made positive impression on the study participants. However, the conclusions of this study should preferably be confirmed among health researchers and research assistants who have actually used OpenXdata in their research.

It is recommended to conduct the evaluation of OpenXdata in real health study focusing on all the functions of OpenXdata. Also comparison between OpenXdata and the paper forms should be done to get clear picture of the usability and desirability of OpenXdata in health research.

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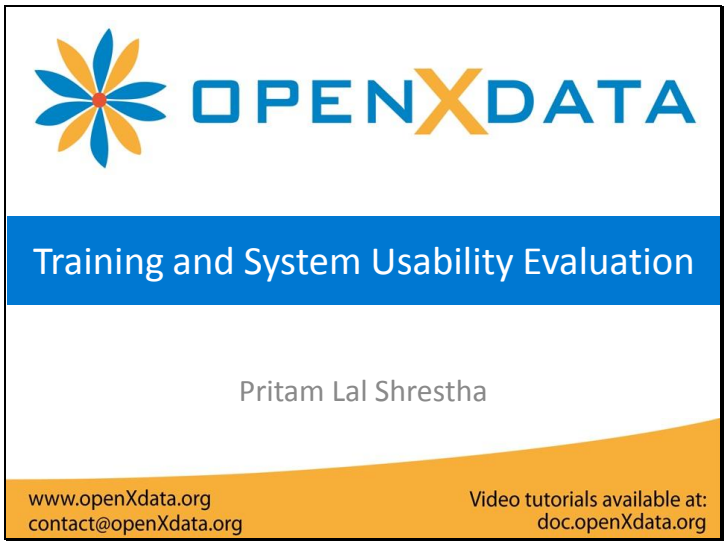
APPENDICES

Appendix A: PowerPoint slides for OpenXdata training

Slide 1



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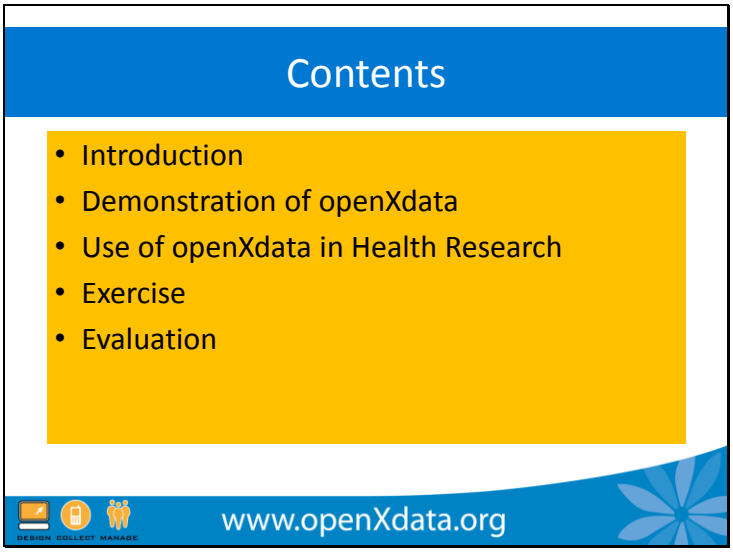

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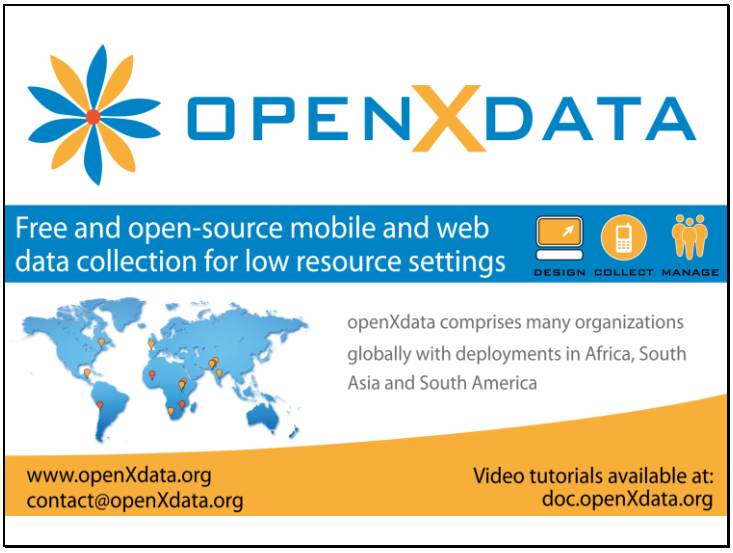

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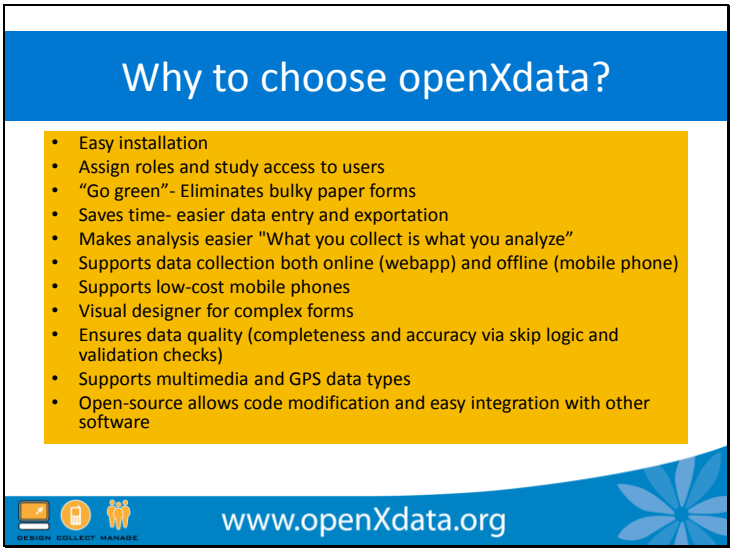

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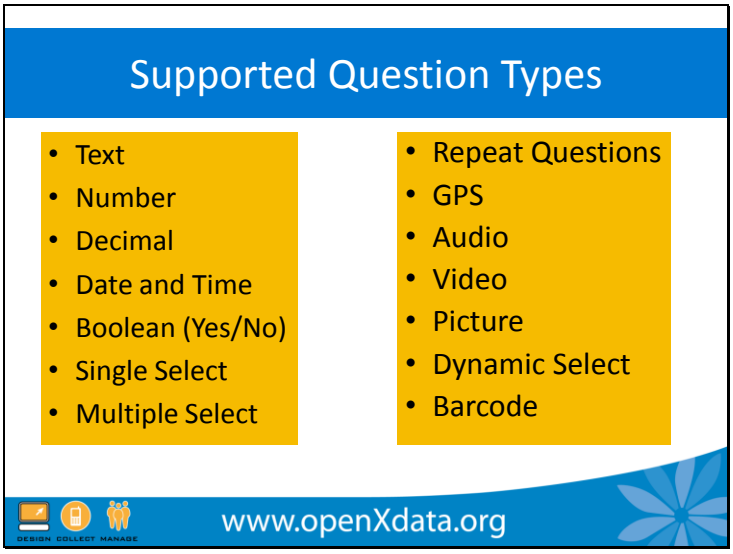
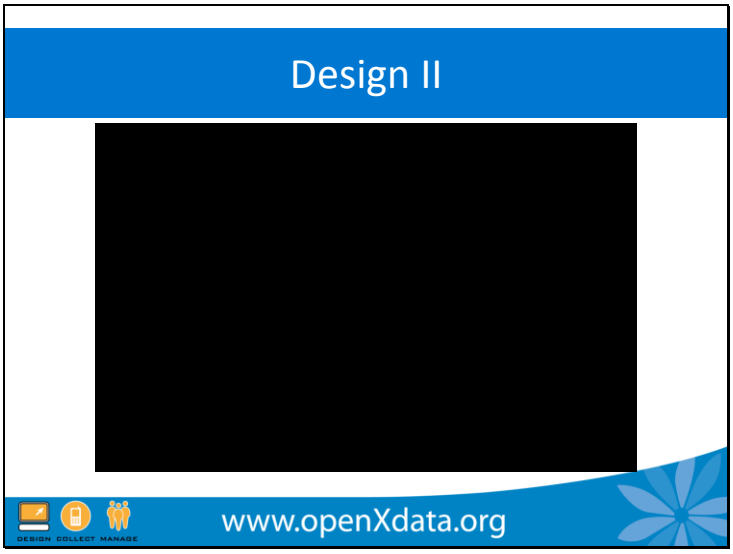


Slide 6

Slide 7



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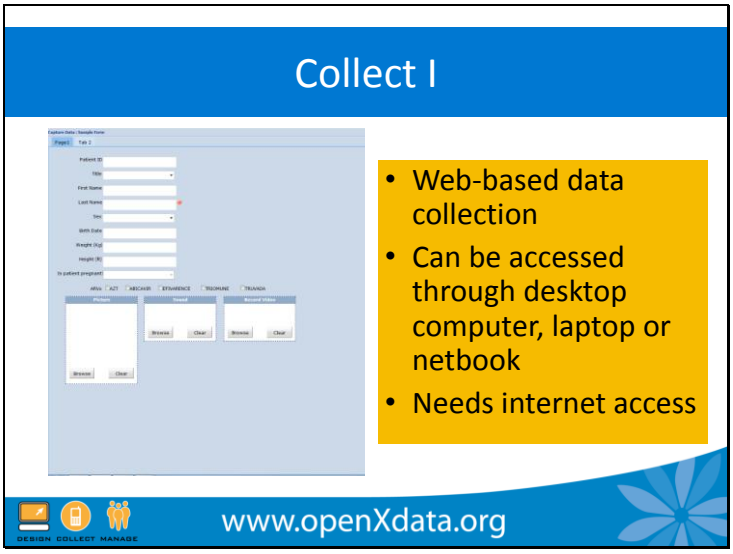


Slide 9

Collect II

- Basic Java enabled mobile phones
- Requires higher end phone for GPS and multimedia data type
- Needs internet access to download studies and upload data.

DESIGN COLLECT MANAGE www.openXdata.org

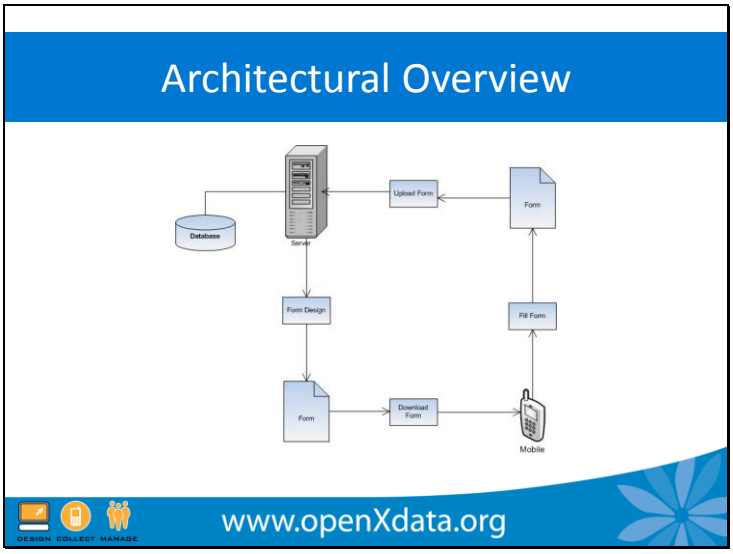
Slide 10

Manage

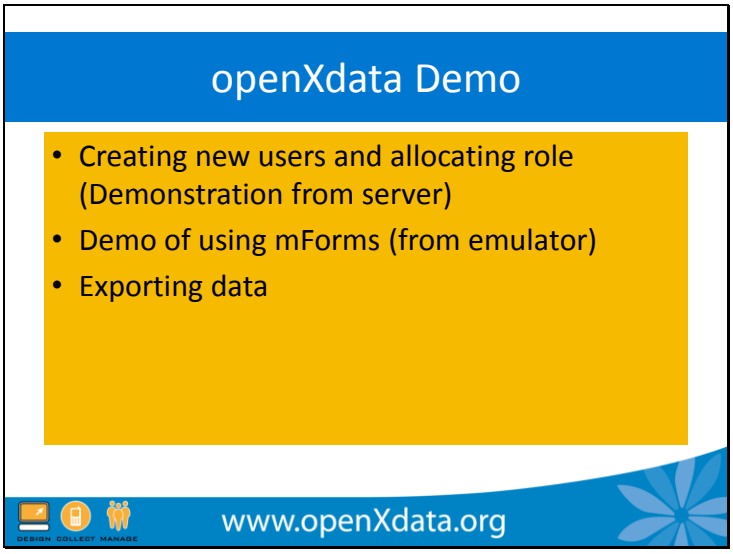
- Host on your own servers
- Create users
- Set roles and permissions for users e.g.: Administrator, Study Manager, Data Manager, Data Collector, Mobile User.
- Manage unprocessed data
- Export data in csv format

DESIGN COLLECT MANAGE www.openXdata.org

Slide 11

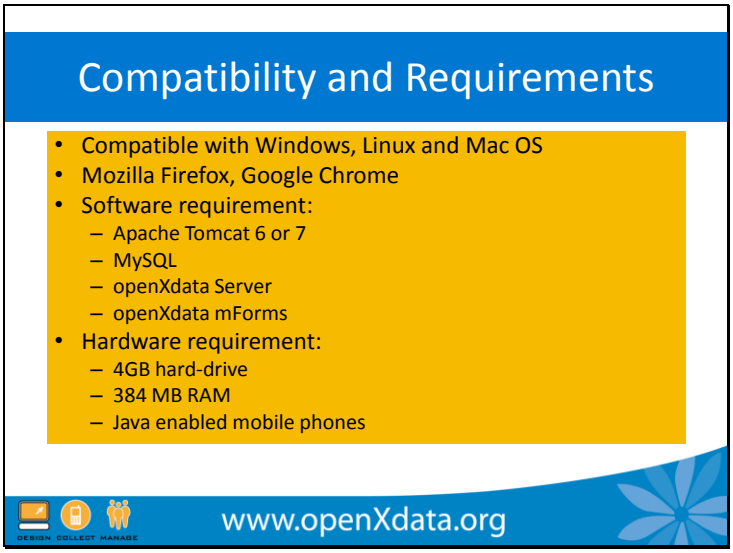


Slide 12



Slide 13

Slide 14



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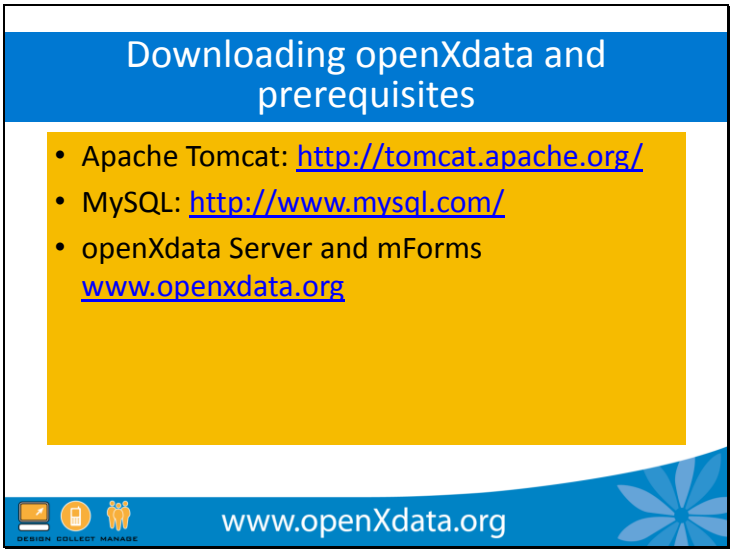

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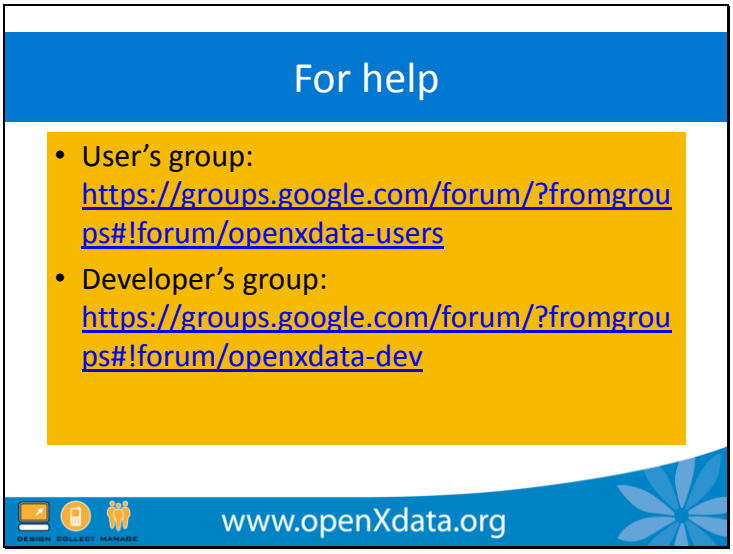
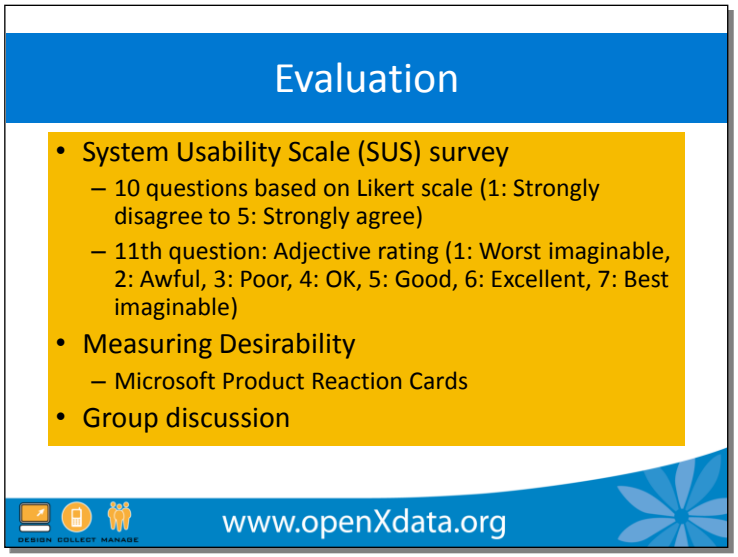


Slide 20

Slide 21


Evaluation
• System Usability Scale (SUS) survey
– 10 questions based on Likert scale (1: Strongly disagree to 5: Strongly agree)
– 11th question: Adjective rating (1: Worst imaginable, 2: Awful, 3: Poor, 4: OK, 5: Good, 6: Excellent, 7: Best imaginable)
• Measuring Desirability
– Microsoft Product Reaction Cards
• Group discussion
www.openXdata.org

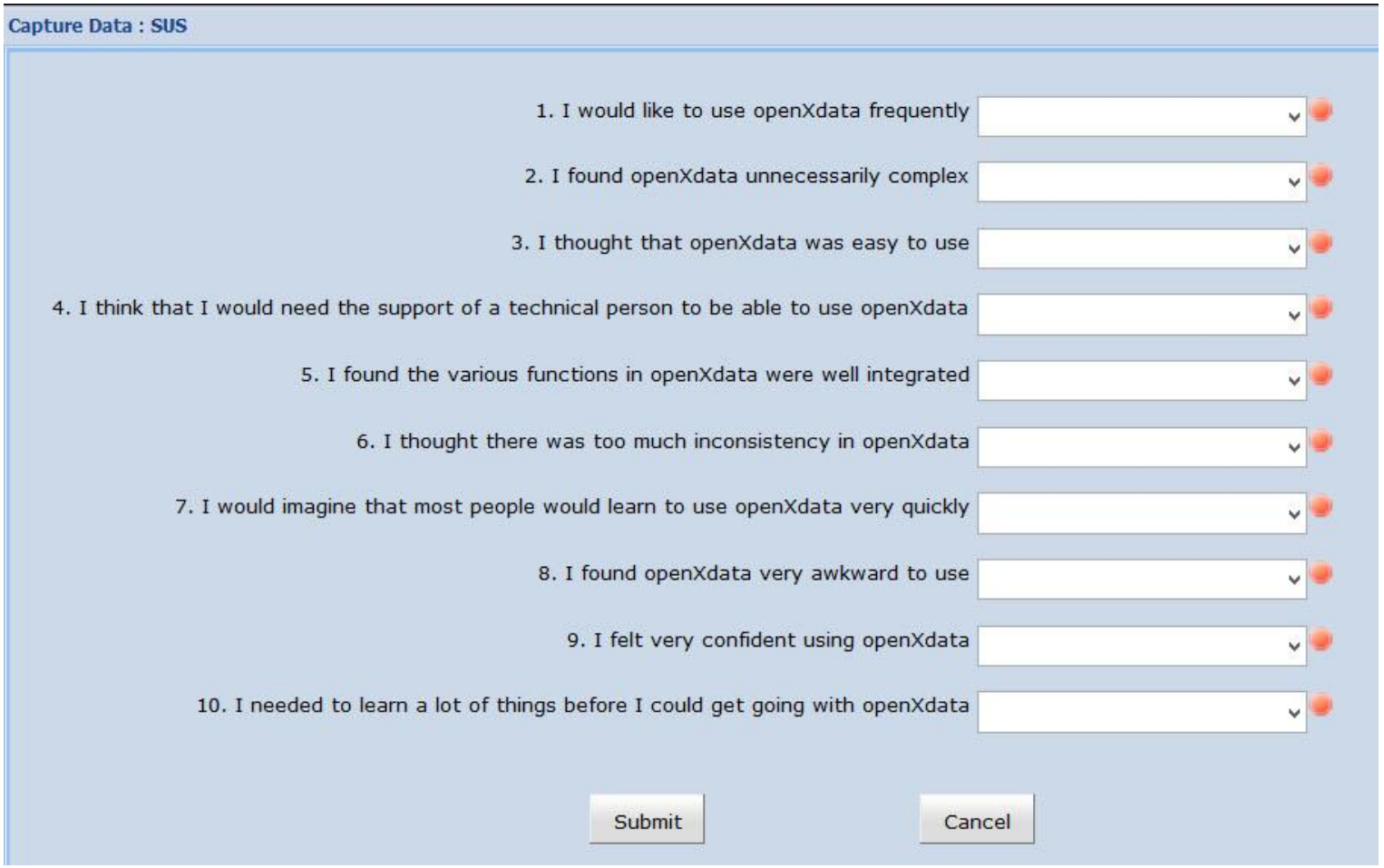
Appendix B: Sample form for workshop

OpenXdata Training - Sample Question Form

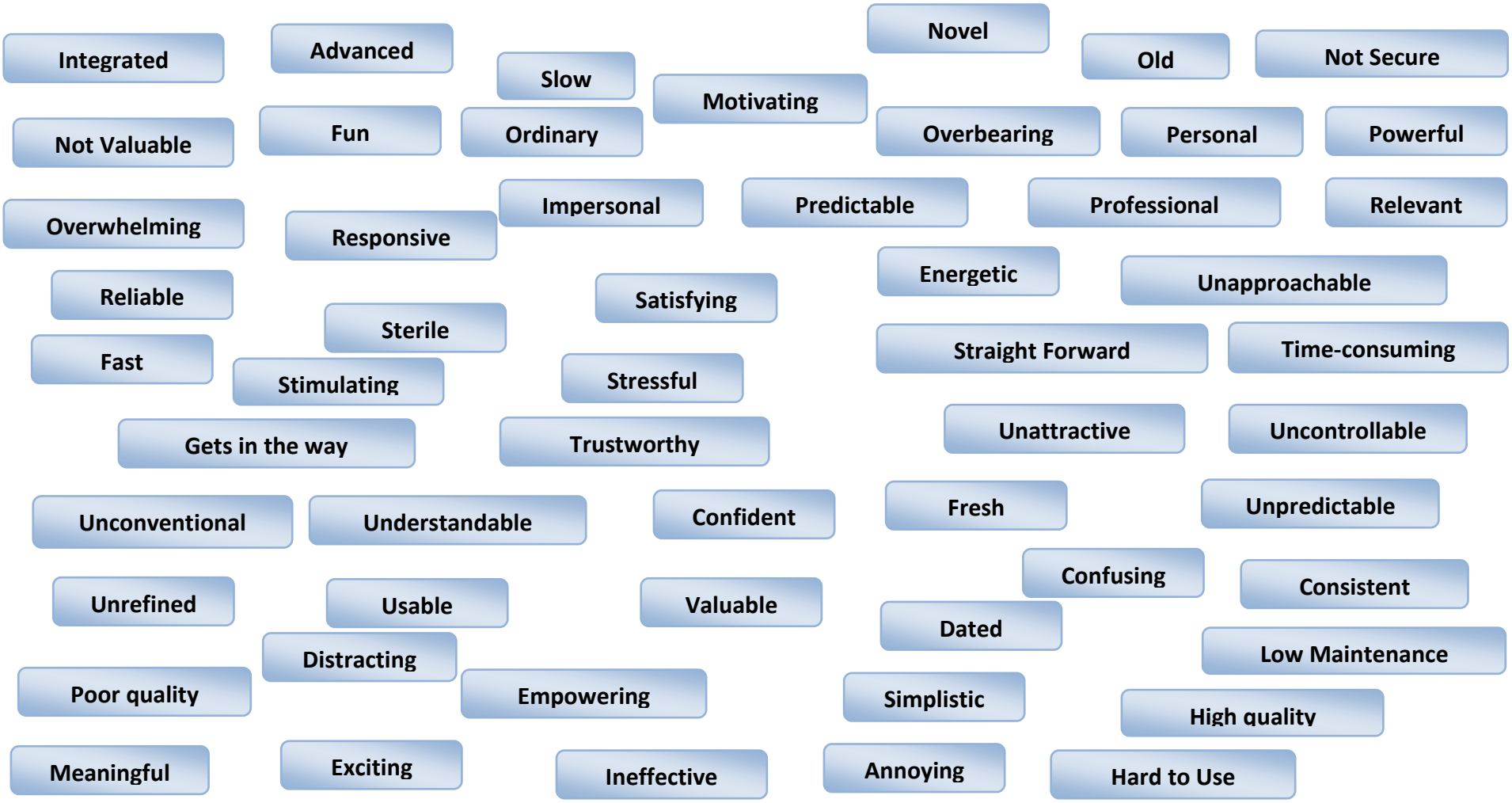
Question No.	Question	Data type	Remarks
1	Start date and Time	Date and time	Hidden question
2	Patient Id	Numeric	
3	Title	Single Select	Option1: Mr. Option 2: Mrs. Option 3: Miss
4	First Name	Text	
5	Last name	Text	Make Required
6	Sex	Single Select	Option1: Male Option2: Female
7	Birth date	Date	
8	Weight (Kg)	Decimal	
9	Height (cm)	Number	
10	Is patient pregnant?	Boolean	**Skip Logic: Enable if Sex is 'Female'**
11	ARV s	Multiple select	Option 1: AZT Option2: ABICAVIR Option 3: EFIVARENCE Option 4: TRIOMUNE
12	Picture	Picture	
13	Sound	Audio	
14	Recorded Video	Video	
15	Location	GPS	

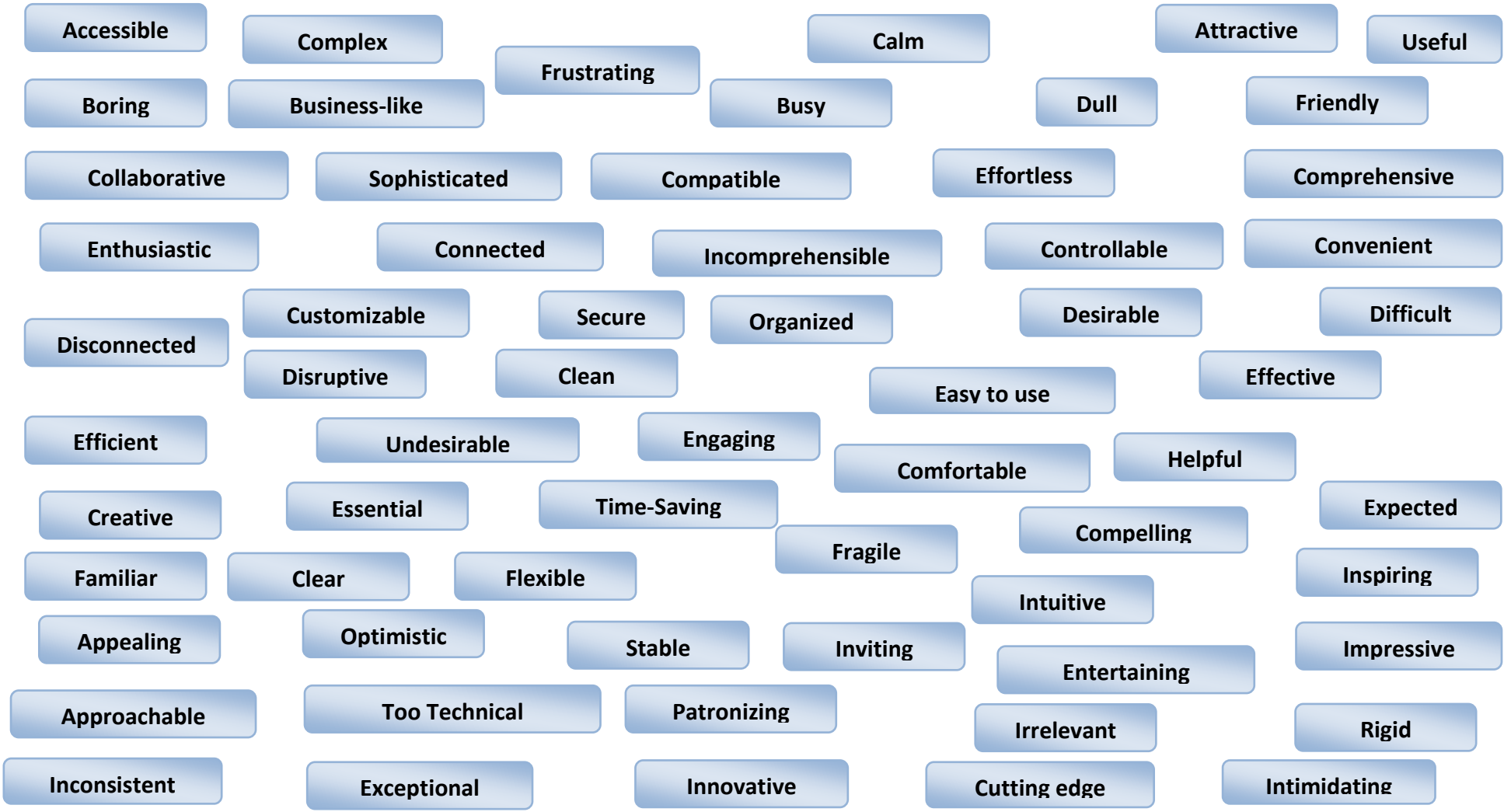
16	Continent	Single Select	Option 1: Asia Option 2: Europe Option 3: Africa
17	Country	Single Select Dynamic	**If Q15 is Asia**, Option 1: India Option 2: Pakistan Option 3: Nepal Option 4: China **If Q15 is Europe**, Option 1: Belgium Option 2: Germany Option 3: Norway Option 4: UK **If Q15 is Africa,** Option 1: Uganda Option 2: Ethiopia Option 3: Sudan Option 4: Tanzania
18	Number of Children	Number	
19	Details of Children	Repeat	Option 1: Age Option 2: Sex **Validation Logic:** **Length is equal to Number of Children** **Error message:** Number of entries should be equal to the number of Children
20	End Time	Time	

Appendix C: Snapshot of SUS survey in OpenXdata web form



Appendix D: Product Reaction Cards used for data collection




Accessible
Complex
Frustrating
Calm
Attractive
Useful
Boring
Business-like
Busy
Dull
Friendly
Collaborative
Sophisticated
Compatible
Effortless
Comprehensive
Enthusiastic
Connected
Incomprehensible
Controllable
Convenient
Customizable
Secure
Organized
Desirable
Difficult
Disconnected
Disruptive
Clean
Easy to use
Effective
Efficient
Undesirable
Engaging
Comfortable
Helpful
Creative
Essential
Time-Saving
Compelling
Expected
Fragile
Familiar
Clear
Flexible
Inspiring
Intuitive
Appealing
Optimistic
Stable
Inviting
Impressive
Entertaining
Approachable
Too Technical
Patronizing
Irrelevant
Rigid
Inconsistent
Exceptional
Innovative
Cutting edge
Intimidating

Appendix E: Form for listing Product Reaction Cards

List the selected Product Reaction Cards

……	……	……
……	……	……
……	……	……
……	……	……
……	……	……
……	……	……
……	……	……
……	……	……
……	……	……

Appendix F: Top 5 cards listing form

List top 5 cards among the selected cards

Product Reaction Card	Reason behind selecting this card (1 or 2 sentences)
1.	
2.	
3.	
4.	
5.	

Appendix G: Scores given by participants for SUS statements

Participant	SUS statements									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
I	4	1	5	2	4	1	5	1	4	3
II	5	2	4	2	5	3	4	1	4	2
III	3	2	3	4	3	3	2	2	2	2
IV	3	2	4	2	3	3	4	3	3	4
V	4	1	3	5	1	1	4	1	3	3
VI	4	2	3	4	4	2	5	1	5	2
VII	3	1	3	1	3	3	3	1	5	3
VIII	5	1	5	2	4	2	5	2	4	1
IX	5	2	5	4	4	1	4	1	5	3
X	4	2	4	1	5	2	4	2	5	2
XI	5	3	3	5	5	1	4	4	5	1
XII	4	1	2	2	5	1	5	1	5	2

Appendix H: SUS score calculation

Participant	SUS statements										Total Score	SUS Score (Total score*2.5)
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10		
I	3	4	4	3	3	4	4	4	3	2	34	85
II	4	3	3	3	4	2	3	4	3	3	32	80
III	2	3	2	1	2	2	1	3	1	3	20	50
IV	2	3	3	3	2	2	3	2	2	1	23	57.5
V	3	4	2	0	0	4	3	4	2	2	24	60
VI	3	3	2	1	3	3	4	4	4	3	30	75
VII	2	4	2	4	2	2	2	4	4	2	28	70
VIII	4	4	4	3	3	3	4	3	3	4	35	87.5
IX	4	3	4	1	3	4	3	4	4	2	32	80
X	3	3	3	4	4	3	3	3	4	3	33	82.5
XI	4	2	2	0	4	4	3	1	4	4	28	70
XII	3	4	1	3	4	4	4	4	4	3	34	85
											Mean SUS Score	73.54

Appendix I: Initial selection of Product Reaction Cards

Participant	Responses
I	Integrated, reliable, responsive, understandable, usable, empowering, relevant, time-consuming, consistent, trustworthy, accessible, busy, useful, collaborative, connected, organized, engaging, too technical, innovative, cutting edge, impressive, efficient
II	Relevant, simplistic, understandable, slow, professional, helpful, useful, clean
III	Understandable, usable, predictable, trustworthy, reliable, high quality, simplistic, convenient, efficient, flexible, easy to use, accessible, impressive, organized, relevant, meaningful
IV	Reliable, fast, usable, valuable, exciting, understandable, stimulating, trustworthy, confident, low maintenance, accessible, attractive, useful, approachable, time -saving, organized, controllable
V	Novel, relevant, fresh, empowering, efficient, engaging, convenient, inviting, exciting, compatible, business-like, usable, clean, cutting edge, stimulating, impersonal, fast, meaningful
VI	Fast, meaningful, understandable, straight forward, dated, accessible, efficient, clear, time-saving, clean, useful, organized
VII	Fast, responsive, consistent, accessible, approachable, innovative, easy to use, helpful, effortless, useful, convenient, impressive, organized, customizable
VIII	Reliable, usable, understandable, not secure, professional, relevant, unpredictable, accessible, collaborative, connected, flexible, time-saving, organized, controllable, helpful, friendly
IX	Fun, motivating, personal, powerful, relevant, professional, straight forward, consistent, dated, high quality, empowering, confident, trustworthy, stimulating, reliable, responsive, meaningful, fast, accessible, calm, attractive, useful, friendly, compatible, comprehensive, controllable, convenient, organized, easy to use, clean, efficient, engaging, helpful, creative, expected, clear, innovative, approachable, inspiring
X	Relevant, usable, exciting, fast, reliable, accessible, secure, effective, impressive, helpful, time-saving
XI	Simplistic, satisfying, high quality, organized, convenient, attractive, familiar, time-saving, motivating
XII	Trustworthy, time-saving, easy to use, attractive, empowering, friendly, effective, reliable

Appendix J: Top 5 selected Product Reaction Cards

Participant	Responses
I	Usable, connected, innovative, efficient, empowering
II	Clean, slow, professional, understandable, simplistic
III	Easy to use, relevant, accessible, reliable, meaningful
IV	Reliable, understandable, fast, confident, approachable
V	Novel, engaging, compatible, efficient, stimulating
VI	Fast, understandable, time-saving, useful, organized
VII	Fast, helpful, accessible, effortless, easy to use
VIII	Accessible, time-saving, connected, not secure, understandable
IX	Empowering, meaningful, easy to use, inspiring, innovative
X	Impressive, time-saving, accessible, helpful, secure
XI	High quality, familiar, time saving, organized, convenient
XII	Easy to use, friendly, time-saving, attractive, trustworthy