Developing and testing for usability within a low resource context

An action case study of the School report card in the Gambia

Alxhip Halilaj & Lars-August Udnesseter Johnson

Master thesis

Informatics: Programming and System Architecture

60 credits

Department of Informatics

The Faculty of Mathematics and Natural Sciences

UNIVERSITY OF OSLO

June 14, 2021

Abstract

The Gambian Ministry of Basic and Secondary Education (MoBSE) has a goal of making decision-making more data-driven at all levels of the education hierarchy. One of their measures to achieve this goal is the social accountability tool; the School report card. A tool within the Gambian Education management information system (EMIS) used to illustrate the performance, resources and efficiency of every school in the Gambia. At the beginning of this project, the School report card was an MS Excel application managed and used by a handful of people who distributed the scorecards to the local communities where they could be presented on paper. The aim of this project was to migrate technologies from MS Access and MS Excel to a third party web application within the DHIS2 platform. This migration would enable more users to select whatever School report card they would like to see, at any point in time. To ensure that the application would be usable for a wider range of users, a usability analysis was conducted through usability testing as the selected usability evaluation method (UEM). The design and functionality was updated based usability design principles and findings made through four iterations of usability testing.

Qualitative research has been employed using the action case research method to investigate the use patterns and value of the School report card within the Gambian EMIS. Existing literature concerns projects that design for usability in developing countries. However, the practical implications of this process are not covered to a significant extent. Findings from this project resulted in a set of practical recommendations for designing and developing for usability within low resource contexts. The findings of this thesis indicate that remote usability testing is achievable even without visiting the context where the system will be used. It requires some unique precautions and introduces some trade-offs. Existing literature implies that remote usability testing is conducted with a participant setup, but the findings of this thesis resulted in a practical framework that suggests that remote usability testing within a low resource context should be conducted with a pre-prepared laboratory.

Acknowledgement

We would like to thank our supervisor Terje Aksel Sanner for his guidance and collaboration throughout this project. Furthermore we need to thank our main contacts in the field, Alpha Bah, Jerry Aziawa, and Seedy Jallow. This thesis would not have been possible without all of you. Thank you Øystein Knudsen for being a great collaborator on the application we developed. Finally we would like to thank our friends and families for their unconditional support.

Table of Contents

Table of Contents iii
List of Tables iv
List of Figures vi

1 Introduction **1**
1.1 Research context 3
1.2 Personal Motivation 4
1.3 Research question 4
1.4 Thesis layout 5

2 Literature Review **8**
2.1 Usability 9
2.2 Remote usability testing 10
2.3 Usability in low resource contexts 12

3 Usability frameworks **15**
3.1 Usability 15
3.2 Usability design principles 18
3.3 Remote usability testing 19

4 Context **22**
4.1 Collecting context information 22
4.2 EMIS 23
4.3 DHIS2 24
4.4 Overview of the Gambia 25
4.4.1 Geography 25

4.4.2 Demographics . . . 26
4.4.3 The education system in the Gambia . . . 27
4.4.4 Education structure . . . 28
4.4.5 Resources . . . 28
4.4.6 Schools during the pandemic . . . 29
4.5 Stakeholders . . . 29

5 Methods **33**
5.1 Research method . . . 33
5.1.1 Relevant methods for this thesis . . . 34
5.2 AR cycles . . . 38
5.3 Data collection . . . 42
5.3.1 Data collection methods . . . 42
5.3.2 Ethical considerations . . . 46
5.3.3 Participants . . . 47
5.3.4 Technologies used for data collection . . . 49
5.3.5 Data analysis . . . 49
5.3.6 Data conclusion and limitations . . . 51

6 Application development **54**
6.1 The school report card . . . 54
6.2 DHIS2 schoolcard . . . 57
6.3 Technologies used . . . 62
6.4 Development tools . . . 62
6.5 Development environment . . . 63

7 Remote usability testing, prototyping and findings **66**
7.1 Remote usability testing . . . 66
7.1.1 Test plan . . . 67
7.1.2 The test laboratory . . . 68
7.1.3 The test administrator/moderator . . . 69
7.1.4 The test observer . . . 70
7.1.5 The test supervisor . . . 70
7.1.6 Recruiting participants . . . 70

7.2 The testing process 72
7.3 Prototyping and usability design 74
7.3.1 Test iteration one 75
7.3.2 Test iteration two 78
7.3.3 Test iteration three 80
7.3.4 Test iteration four 84
7.4 Usability testing process summary and findings 86

8 Discussion and Analysis **89**
8.1 Usability 90
8.1.1 Usability obstacles on low resource contexts 90
8.1.2 Usability attributes 92
8.1.3 Design principles 93
8.1.4 Usability guidelines for low resource contexts 94
8.2 Remote usability testing 96

9 Conclusion **105**
9.1 Practical contributions 106
9.2 Theoretical contributions 106
9.3 Future work 108

List of Tables

5.1 Research method attributes 37
5.2 Main data collection methods 43

7.1 Iteration one summary table 77
7.2 Iteration two summary table 80
7.3 Iteration three summary table 83
7.4 Iteration four summary table 86
7.5 Usability issues 87

8.1 Usability guidelines 96

List of Figures

2.1 Local laboratory testing 10
2.2 Remote usability testing 11

3.1 Model of attributes of system acceptability [21, p.25] 16

4.1 The Gambia [6] 26
4.2 Literacy rates from UNESCO[39] 27

5.1 IS research methods triangle[5, p.7] 34
5.2 AR 5-stage cycle[34, p.14] 35
5.3 Cycle 1 overview 39
5.4 Cycle 2 overview 40
5.5 Cycle 3 overview 41
5.6 Participants 48

6.1 School report card 56
6.2 Improved School report card 59

7.1 Remote usability testing 67
7.2 Local test setup 69
7.3 Problem identification graph from [27, p.156] 71
7.4 Benefit cost ratio[21, p.174] 71
7.5 Stages of testing, [21] 73
7.6 First prototype 76
7.7 Autocomplete 79
7.8 Input validation modal 82

7.9 Illustrations map 84

8.1 Local lab testing 97
8.2 Remote usability testing with a pre-prepared lab 100

Acronyms

BCS Basic Cycle School.

DHIS2 Disctrict Health Information System 2.

EMIS Education Management Information System.

HCI Human-Computer Interaction.

HISP Information Systems Program.

HISP WCA HISP West and Central Africa.

HMIS Health Management Information System.

ICT Information and Communications Technology.

ISO International Standards Organization.

LBE Lower Basic Education.

MoBSE Ministry of Basic and Secondary Education.

PPARBD Planning Policy Analysis Research and Budgeting Directorate.

PTA Parent-Teacher Association.

SIG School Improvement Grant.

SMC School Management Committee.

SQAD Standard and Quality Assurance Directorate.

SSE Senior Secondary Education.

TA Thematic Analysis.

UBE Upper Basic Education.

UEM Usability Evaluation Method.

UiO University of Oslo.

Chapter 1

Introduction

Social accountability initiatives have been growing significantly in popularity over the last decade[30, p. 1]. These initiatives rely on community participation in processes that aim to improve performance in public sectors and demand accountability from service providers and other involved actors. On many projects worldwide, social accountability tools are increasingly used to improve service delivery and performance. These projects find application in many sectors such as health, public transport, education, etc., and come in several variations, including social audit, participatory budgeting, community score card, and so on[30, p. 1]. One of the projects that have found the use of these initiatives is the School report card in the Gambia which is a version of the community score card. The School report card is a digital product created to support data-driven decision-making in educational systems and increase community involvement in this process.

The first version of the School report card in the Gambia was created in 2008 using Microsoft Excel and Microsoft Access. Even though the tool is available in digital version, at the sub-national levels, it is mainly used in analog format. Considering the limitations that this tool has today, which are described in more detail in chapter 6, we can say that these technologies are not suitable for the School report card's purpose. At the Ministry of Basic and Secondary Education (MoBSE) request in the Gambia, the University of Oslo decided to contribute to this project and make the tool part of the Disctrict Health Information System (DHIS2) platform. DHIS2 is an open-source,

web-based platform focusing on Health Management Information Systems (HMIS). It is the world's largest HMIS platform and is used in 73 low and middle-income countries. Following the health domain's success, DHIS2 is extending its software platform by introducing DHIS2 for Education. By taking advantage of the long experience with HMIS systems, the platform is now providing a stable, scalable, and customizable product that can be utilized for Education Management Information System (EMIS) around the world. Since DHIS2 for Education is now a part of the platform core, it allows integration with other DHIS2 apps, controlled data access, and helps in data analysis for all education system level[10]. These factors influenced the decision to migrate technologies of the School report card part into the DHIS2 platform as a third party application. This integration aims to utilize the platform's qualities to improve the EMIS of several developing countries in Africa, starting with the Gambia.

The integration of the School report card into the DHIS2 platforms will increase the accessibility of the application, and therefore we are expecting a significant increase in the user base. Considering the large number of people who will be able to use the application and their vastly different literacy and digital proficiency levels, this thesis aims to test and improve the usability of the product in an effort to make the application useful to as many end-users as possible. To guide our work throughout this process we applied three usability frameworks. The development and design of the prototypes for the School report card were guided by the usability attributes defined by Nielsen. In order to achieve these attributes, we filtered out and applied a set of usability design principles suggested by Jordan. In addition to this, we took into consideration the contextual concerns discussed by Li, to build on his experiences when developing for usability in low resource contexts. The result of this process is a set of recommendations that can be used as a guideline while developing systems and researching in low resource contexts. In addition, we present our experiences through a new remote usability testing framework.

1.1 Research context

The project was introduced to us at the end of 2019, and we were very intrigued by the project description. In the fall of 2020, we were introduced to the existing School report card tool and the project context. During this period, we started developing the web application and finished the first full version at the beginning of January 2021. After completing this step, we created our usability testing plan and designed the application's potential improvements, which resulted in our first prototype. During March, we deployed four prototypes which were used for the four iterations of usability testing. At the end of each iteration, we conducted interviews with each participant. Also, before starting the usability testing, we had several interviews with representatives from MoBSE and HISP West and Central Africa (HISP WCA), which provided us with helpful information from the field. The usability testing, interviews, and the focus group were some of the main methods used in the data collection process. This process helped us better understand the thesis's context, the School report card's value, and the limitations of the existing tool.

The development team who built the initial web application consisted of three master students from the University of Oslo (UiO). Throughout the rest of the thesis, this trio is referred to as the development team, while the authors of this thesis are referred to as the research team. The digital product of this project has been used in two separate master theses. During the whole research process, we were supported by our contact in the Gambia from MoBSE and HISP WCA. The usability testing process was made enabled by three representatives from the Gambian MoBSE. Finally, guidance throughout the development and writing process was provided by our supervisor at the department of Informatics at UiO.

1.2 Personal Motivation

Throughout our education, we have attended several courses related to software development and information systems. The department of Informatics at UIO is renowned for its work on information systems, which translates into interesting subjects for the students. Our motivation for selecting this master thesis was to combine our skills in software development with our knowledge about platforms and information systems to produce something of value to the community in the Gambia while contributing with research.

The thesis was originally intended to include field research from the Gambia as a part of the data collection method. However, due to the unfortunate global circumstances, this proved impossible. Having the opportunity to personally work with end-users in a developing country like the Gambia was initially a huge motivation for us, but Covid-19 made us adapt. The software product developed for this project will reinforce arguments made in the discussion chapter.

1.3 Research question

The focus of this thesis is usability in low resource contexts. The existing literature presents several usability attributes and usability design principles but to our knowledge their focus in low resource contexts is limited. By combining the existing literature with our theoretical and practical work performed during this process, we try to identify the main factors that affect usability in such contexts. We aim to achieve this by answering the following question:

What are the factors to consider while developing for usability within a low resource context?

This research question was answered by first processing existing literature, then adapt it to this research context. The output was a set of recommendations based on our

experiences for designing and developing for low resource contexts.

Due to the Covid-19 pandemic, we were not able to travel to the Gambia to test the product that was developed during this research process. As we found ourselves in this situation, we decided to look for alternative methods to test our usability design decisions. In order to achieve this and to help other researchers and developers in similar situations like ours, we try to answer the following question:

How can remote usability testing be used as a usability evaluation method within a low resource context?

Remote usability testing literature provides great testing guidelines for testing in developed countries with solid infrastructure. However, we could not find a suited framework for our use case. The context of the project and our experiences as testers resulted in a remote usability testing framework that can be used in future projects.

1.4 Thesis layout

Chapter 2 presents the background literature on which this thesis is based upon. It gives a brief description of the usability in low resources contexts and platforms.

Chapter 3 describes the conceptual frameworks used on the thesis.

Chapter 4 focuses on the context of the thesis, as well as the context for the application development. It includes an overview of the Gambia with focus on its education system, and a description of EMIS and DHIS2

Chapter 5 presents the methodology chosen to conduct the research process and the methods used for data collection and analysis.

Chapter 6 gives an overview of the existing School report card tool followed by a detailed description of the development process of the new application.

Chapter 7 describes the remote usability testing process followed by an overview of

the developed prototypes and test iterations. In the end, it presents a summary of the findings, limitations and conclusions of the usability testing process.

Chapter 8 presents a discussion related to the research process and our findings, and analyse the challenges and limitations faced during this process

Chapter 9 concludes the thesis by summarizing the findings and presenting potential directions for future work.

Chapter 2

Literature Review

The goal of the collaboration with the Gambian MoBSE was to migrate technologies from Excel to a DHIS2 third party application, and to re-design and evaluate the usability of this new product. This usability evaluation was necessary because the migration of technologies would enable several new users to utilize the digital product. In order to evaluate the usability of the developed product, the research team decided to conduct usability testing, and due to the remote nature of this entire project it had to be conducted remotely. Since we were prohibited from visiting the context where the application would be used, we analysed research related to the implications and challenges of designing and developing for low resource contexts. Theory about usability, remote usability testing and implications and challenges of designing for low resource contexts were the main areas of research that directly links to the process and outcome of this thesis. We present this theory in the upcoming sections.

2.1 Usability

Usability is a term used to describe how usable a product is. It is widely recognized as a desired quality of digital products within the field of human-computer interaction (HCI). The term was coined in the 1980s to replace the term "user friendly"[4]. It has since been defined in several different ways.

Nielsen explains in the book Usability Engineering that usability describes how well users can use a system's functionality. However, he stresses that usability is not a one-dimensional property of a user interface but rather a product of five usability attributes. These five attributes being; learnability, efficiency, memorability, errors, and satisfaction [21, p.25,26].

Shackl points out the usability of a system is not only referring to ease of use but that it also includes efficacy or the effectiveness of human performance. He suggests a definition of usability to be; "The capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks within the specified range of environmental scenarios"[2, p. 340].

The International Standards Organization (ISO), responsible for developing quality standards, has presented an alternative definition. They define usability as "The effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments"[42].

Even though these definitions emphasize different points, all three definitions state that usability is a term used to define how effectively a user can interact with the system within a specific context. Building on the idea that usability can be measured - different evaluation methods have emerged. We have adopted three usability frameworks to guide our design and data analysis process. These are presented in chapter 3.

2.2 Remote usability testing

Usability testing is one of the main methods used to evaluate the quality of a user interface[22, p.1]. This type of usability evaluation method (UEM) tests a users' ability to identify problems within a system by completing a set of pre-defined tasks. The conventional way to perform usability testing is to invite test subjects to a laboratory and test the system under the supervision of an evaluator[1, p.1405]. However, when the test evaluator is separated from the test subject spatially or temporally, one can utilize remote usability testing. The difference of conventional and remote testing is illustrated in 2.1 and 2.2.

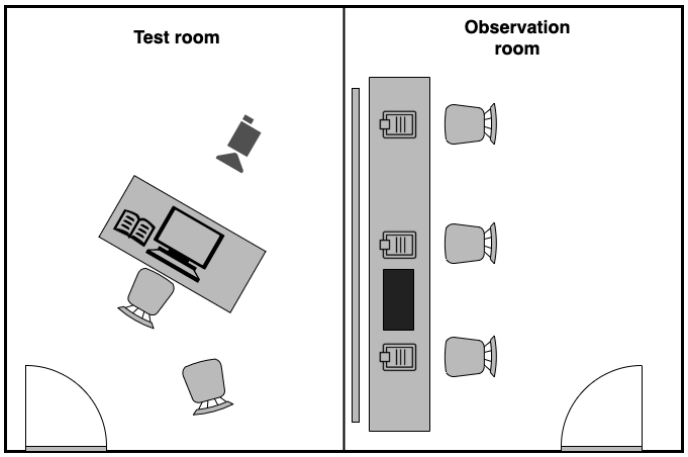


Figure 2.1: Local laboratory testing

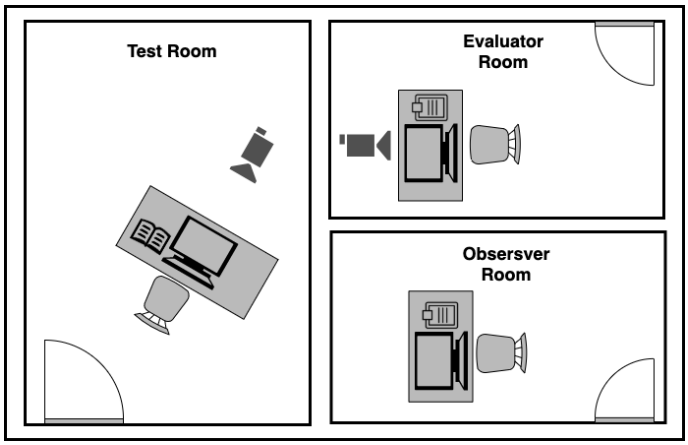


Figure 2.2: Remote usability testing

Remote usability testing entails that the test subject performs tasks and evaluates the system from a distance. A set of digital tools enables this process, tools which have drastically improved in recent years. Andreasen et al. present two different approaches to remote usability testing; synchronous and asynchronous. Remote synchronous testing is described as a live user test where the test moderator and test subject are separated in space. In comparison, when conducting remote asynchronous testing the test moderator is separated from the test subject in both space and time. In this case the test subject completes a set of tasks and records their own performance. This footage is then reviewed at a later time.

Thompson et al., Andreasen et al., and Huang et al. have identified quite similar pros and cons of conducting the different methods of usability testing[37][1][18]. Remote testing removes the problem of having a homogeneous subject pool as it enables a broader array of users to be tested. More heterogeneous subject pools can be achieved because there are no travel restrictions, and the process is overall less time-consuming. Furthermore, the literature seems to agree that there is no significant difference in remote synchronous testing and laboratory testing when it comes to identifying problems provided the test process is planned well[18, p.397]. However, remote asynchronous testing is generally known to be worse in regards to identifying problems than the other methods[37, p.136].

2.3 Usability in low resource contexts

Nowadays, analog information systems in developing countries are increasingly digitalised. The paper-based routines are now replaced with digital user interfaces (UI). Li M. gives an overview of three main obstacles with usability encountered during the design process of information systems in developing countries. These obstacles are constraints introduced by legacy design, scale and heterogeneity of user groups, and constraints introduced by software[24].

Constraints introduced by software. A lot of information software used nowadays is generic and off-the-shelf [13]. They are built to support variety and aid a wide range of user groups. The global designers of these systems have significant geographical and cultural differences from the end-users, and they focus on the usability of the system's widely used aspects [45]. This approach's downside is the lack of support for specific use-case implementation. To make these systems usable within a particular context, additional customization needs to be implemented. One frequently used approach to achieve this is building third-party applications [24].

Constraints introduced by legacy design. To make the transition from analog to digital easier for the end-users, the designers tend to build the digital layout as similar as possible to the analog layout. However, during this transition, some of the functionalities of the original paper-form version are not suitable for the digital tool [23]. The local designers are frequently faced with difficult decisions, and they need to make a trade-off between implementing familiar concepts and presenting new data entry practices. To overcome this obstacle, the local designers have to find the aspects of the existing system that are useful for the end-users and find an appropriate way to implement them in the digital system [24].

Scale and heterogeneity of user groups. As mentioned in the previous sections, to make the generic system useful for specific contexts, additional customizations need to be made. In many cases, these customized systems are used by a considerable amount of end-users, who have a vast difference in the mental model and experience with the system. The designs and functionalities suitable for novice users can be inefficient for

experienced users, and the complex functionalities that can be very useful for experienced users can confuse novice users. This situation presents another obstacle for the designers who need to decide the user groups they have to design for and how and who to involve in the process of system design. A solution to this obstacle, which can not always be possible, is to allow end-users to design their applications themselves based on their needs [24].

Chapter 3

Usability frameworks

After analysing related literature we selected a set of usability frameworks to guide our project. The sections of this chapter present these frameworks, explain why they were selected, how they were used, and how they were altered to suit better the context of this thesis.

3.1 Usability

Ensuring that the developed application was both usable and understandable for the target user groups was pivotal for the systems acceptance within the context. Recognising that there was a large gap in literacy levels as well as computer proficiency in the Gambia, we expected some design compromises to be made. In order to support the goal of increasing the amount of potential end users, a usability analysis of the application was required. As described in chapter 2, there are many definitions of usability. In this thesis we have used Nielsens definition, and used the framework presented in the book Usability Engineering. This book can be considered a cornerstone of the usability literature, and guided this project to a significant extent. However, it is quite an old book, especially considering it is written about a rapidly developing field. In addition,

there are some topics that are not described in great detail, but has a high level of relevance for this project. Therefore, other frameworks also influenced this project. These will be presented further below.

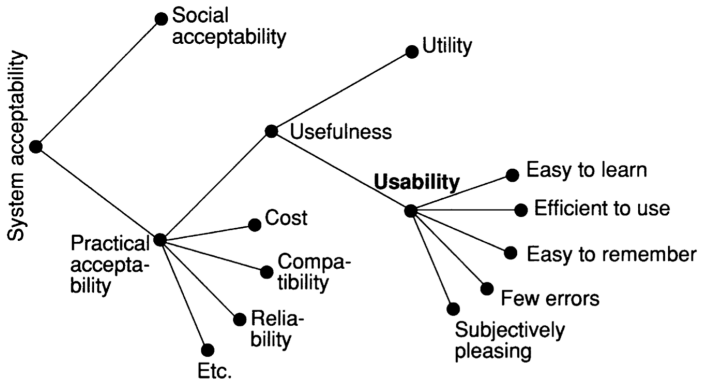


Figure 3.1: Model of attributes of system acceptability [21, p.25]

The term usability is used as a part of evaluating a systems overall acceptability, like seen in figure 3.1. Usability and utility are derived from the term usefulness, which again is a part of a system's practical acceptability. Usefulness describes the issue of whether a system can be used to achieve some desired goals. Utility is the question of whether the functionality of the system in principle can do what is needed, and finally usability is the question of how well users can use that functionality[21, p.25]. Usability is measurable and can be tested through prototypes or finalized products. Nielsen explains how usability is not a one-dimensional property of a user interface, but rather a product of five usability attributes[21] described below.

Learnability

The system should be easy to learn and the users can start working in a short amount of time. Nielsen describes learnability as the most fundamental usability attribute, as every user's first interaction with the system will be learning how to use it. Traditionally, new users will experience a steep learning curve, unless the system has a very low complexity or they have experience with a legacy system. Learnability is one of the easiest attributes to measure [21, p.28].

Efficiency

After learning how to use the system, the users should be able to have a high level of productivity. For complex systems it can take years to reach the final level of efficiency. In order to measure this usability attribute you need experienced users. Experience can be measured with hours of experience using the tool. In order to evaluate the level of efficiency of users you need to define tasks you would expect experienced users to be able to accomplish [21, p.30].

Memorability

It should be easy to remember how to use the system even after a long period without using it. Casual users, who interact with the system intermittently should be able to use the system at a relatively high level. This usability attribute is less frequently tested, but it can be achieved by performance testing casual users who have been away from the system for a longer period of time[21, p.31].

Errors

The number of errors occurring during the system use should be as minimal as possible and easy to recover from. No catastrophic errors should occur in the system at any time. An error is defined as an action that does not accomplish the desired goal, while a catastrophic error is defined as an undesired action that is difficult or impossible to recover from. The error occurrence rate can be measured during usability testing while the test subject is completing tasks[21, p.32].

Satisfaction

The system should offer a pleasant user experience. This usability attribute is most relevant for systems in a non work environment like video games. It can be measured by simply asking the test subject for their subject opinion about the pleasantness of the system. A single reply is only a subjective opinion, but averaging the results from many users can provide data about the objective satisfaction of the system[21, p.33].

3.2 Usability design principles

Jordan P.W defines ten design principles associated with usability [33]. Since we were part of an ongoing process and both the analog and digital versions of the application had been used for several years, some of the usability design principles were not applicable for our case. Based on the users' existing mental model and prior knowledge, we eventually decided not to make major structural changes to the application. In light of this, we made a filtration on the predetermined list with a focus on the five most relevant principles for our case, being; consistency, compatibility, feedback, error prevention and recovery, and visual clarity. As we gained more contextual knowledge and user feedback, this list was adjusted throughout the process. Here we present a brief description of all the ten principles defined by Jordan.

- Consistency. Designing a product so all similar tasks are done in similar ways.
- Compatibility. Designing a product so that its method of operation is compatible with users' expectations based on their knowledge of other types of products and the outside world.
- Consideration of user resources. Designing a product so that its method of operation takes into account the demands placed on the users' resources during the interaction.
- Feedback. Designing a product so that actions taken by the user are acknowledged and a meaningful indication is given about these actions.
- Error prevention and recovery. Designing a product so that the likelihood of the user error is minimised and so that if the errors do occur they can be recovered from quickly and easily.
- User control. Designing a product so that the extent to which the user has control over the actions taken by the product and the state that the product is in is maximised.

- Visual clarity. Designing a product so that information displayed can be read quickly and easily without causing confusion.
- Appropriate transfer of technology. Making appropriate use of technology developed in other contexts to enhance the usability of a product.
- Explicitness. Designing a product so that cues are given as to its functionality and method of operation.

The main factors we considered while selecting the usability design principles were the project's context and the users' existing mental model and prior knowledge. For projects where the goal is to design and develop systems from the ground up, they will likely have to prioritize these principles differently.

3.3 Remote usability testing

Going into this project, the research team only had some experience using asynchronous remote usability testing tools. This limitation made us look for literature to guide the process of planning and conducting synchronous remote usability testing. Thompson et al. provided a set of recommendations to ensure remote usability tests of high quality[37, p.136]. These recommendations inspired our process to a significant extent and helped us plan for a process tailored to our context.

Thompson et al. observed that usability testing is often perceived as impractical due to users' geographical distribution, limited access to representative users, and difficulties in reproducing test laboratories. This observation motivated a study where the goal was to identify appropriate tools and to define methodologies for effective and efficient remote usability testing[37, p.132]. One of the main contributions of this thesis is a remote testing framework that builds on these guidelines provided by Thompson et al. presented below.

Synchronous testing with a test evaluator is recommended instead of the test subject performing asynchronous testing individually. This approach enables using the thinking aloud method, user feedback, and real-time debriefing [37, p.136].

Select web software that fits the needs of the project. Finding suitable software is essential to conduct and record the planned testing process. Thomson et al. recommend selecting a tool with screen sharing, logging, and voice recording capabilities[37, p.136].

Using tape-recorder as a substitute for microphone recording is suggested should the selected software lack the option to record the test subject's voice. However, this may reduce the voice recording quality and require the test subject to return the tape[37, p.136].

Arranging a meeting to check the test setup is a recommended practice to ensure that the test environment is set up correctly and the test subject knows how to use it. Failing to do this can lead to unwanted interruptions that can be a source of frustration for both parties involved[37, p.136].

Print and send test material by mail in good time before the test. Participants may be unwilling or unable to print out the test material at home. If they are not provided with the test material in good time before the test starts, the test can not be conducted. The material must be marked with a label stating it should only be opened when the administrator says so[37, p.136].

These guidelines were defined based on experiences from the United States, a country with a solid infrastructure and a population with an average digital proficiency level that is quite high. Should this not be the case for other researchers projects', alterations should be planned for. In our case we had to adjust to test in a low resource context. Details about these considerations is presented in chapter 7.

Chapter 4

Context

This chapter aims to present the research context of this thesis, as well as the context for the application development. The current world situation with Covid-19 made us perform the research for this thesis remotely and digitally. This is generally not the suggested approach for a study which is placed in a context that is vastly different from the context where we live our daily lives. In this chapter, we introduce a set of measures taken to overcome the challenges of remote context analysis. This is followed by an introduction to the Gambian EMIS project and a presentation of the DHIS2 platform. Then we present an overview of the Gambia in terms of demographics, geography, and economy. Finally, the Gambian educational system and the stakeholders for this project are described.

4.1 Collecting context information

When this project started, the initial plan was to have two trips to the Gambia to analyze the context and perform our research in the field. This proved impossible, and the research team had to find alternative methods for collecting information about the context. It is crucial to obtain a deep understanding of the context when conducting research in order to identify and solve problems. With this in mind, the research team put great effort into finding alternative methods to gain contextual insight.

One of the primary methods used for gaining contextual knowledge was through remote meetings with the project stakeholders. Representatives from HISP WCA and MoBSE were some of the most influential. These stakeholders and their roles in this project are described in more detail in section 4.5. Early and regular meetings with these stakeholders enabled an initial impression about the context. They provided us with further documentation describing the results of previous work performed in the field. Another useful measure was to read existing master theses written within the same context. These theses contained both written descriptions of the context but they also provided images and links to additional literature. Furthermore, browsing the web to find information about the context through official Gambian websites also proved useful. Informational videos from the context were also studied. The final measure taken was arranging usability testing, interviews, and focus groups as parts of the data collection process presented in chapter 5.

4.2 EMIS

An Educational Management Information System (EMIS) is described by Hua and Herstein as an "institutional service unit producing, managing, and disseminating educational data and information"[17, p. 4]. In the Gambia, these responsibilities are assigned to MoBSE. They are responsible for managing the information flow in the educational system and provide statistics and marketing educational data used in the decision-making process in a reliable fashion. Extending on this definition from Herstein, UNESCO uses a definition with an increased emphasis on the different components that an EMIS is comprised of. "...It (EMIS) is a system of people, technology, models, methods, processes, procedures, rules and regulations that function together to provide education leaders,decision-makers and managers at all levels with a comprehensive,integrated set of relevant, reliable, unambiguous and timely data and information to support them in completion of their responsibilities"[36, p.101]. When working with this project, the research team experienced that an EMIS is more than just the institutional service unit, but an ecosystem of different people, technologies and processes.

UNESCO's Education for All Global Monitoring Report stresses the importance of

understanding the need for data in an EMIS and further explains that failures will occur when too little effort is put into considering who will use the data and for what purpose[36, p.101]. In order to avoid failed EMIS projects, Herstein presented a list of three goals to ensure success:

- Timely and Reliable Production of Data and Information
- Data Integration and Data Sharing among Departments
- Effective Use of Data and Information for Educational Policy Decisions[17, p. 5]

The importance of a data-driven EMIS has been recognized and highlighted by the head of EMIS and ICT units in MoBSE[16, p. 4]. Data and information about the schools and student performance are analyzed and used for educational decision-making in the different levels of the educational hierarchy. Schools can use statistics and data to argue that they need an increase in the school improvement grants (SIG) in order to supply the students with the necessary resources needed to perform well at school. This funding could be used on everything from getting access to more qualified teachers to purchasing more math books. The data can also help parents select what school their children will attend when a choice is provided. This is the goal of the school report card, to visualize information about the schools in a manner that is easily understood, to some extent also for the illiterate population.

4.3 DHIS2

The DHIS2 platform is an open-source information system that mainly supports, but is not limited to, health management[9]. The web-based platform is used to collect, share, visualize and analyze data[11]. DHIS2 is a continuation of the Health Information Systems Pilot Project that took place in South Africa as a part of its reconstruction post-apartheid. The core software development is managed by the Health Information Systems Program (HISP) at UiO, which is further described in section 4.4. The platform operates in over 100 countries, which each has its own instance of DHIS2[11]. For the platform to be useful in vastly different contexts, it has to be highly customizable. This

is achieved through a modular layered architecture, with a stable core and strong API. Third-party applications can then easily be added on top of the platform core. This customizability is what enables the platform to be utilized for fields other than health[9]. These properties are what enables the platform to be utilized by the Gambian EMIS. Other nations in West-Central Africa, like Uganda, can learn from the experiences gained in the Gambia.

The DHIS2 core is developed and maintained by the HISP core team at UIO[41]. It is the most general and robust layer, with an API, metadata model, and other resources. The outer layer contains the Bundled Apps which are apps that come along with the core in the download of the DHIS2 client. That includes applications that are developed and maintained by the team at UIO. Periphery apps are created by 3rd party developers, which is the definition of the application made for this thesis.

4.4 Overview of the Gambia

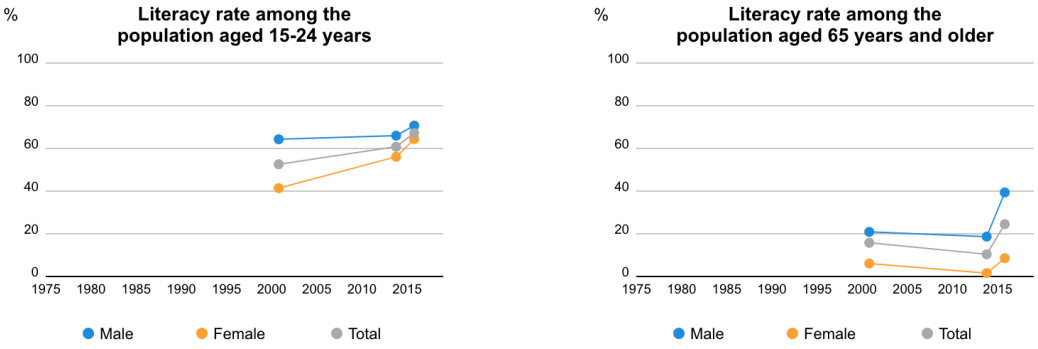
4.4.1 Geography

The Gambia is the smallest country within the mainland of Africa. This small republic is located in Western Africa and is bordering Senegal and the North Atlantic Ocean. The country is divided into 6 regions, and the capital is Banjul[6]. The Gambia gained its independence from the UK in 1965. Being a past British colony is the main reason why the national language is English. However, there are other local languages being practiced such as Mandinka and Wolof.

Figure 4.1: The Gambia [6]

4.4.2 Demographics

The country had an estimated population of 2.35 million and a working force of 779 000 in 2019[43]. The country suffers from high levels of unemployment. Furthermore, the Gambia is a country with poor literacy rates, estimated in 2015 to be a staggeringly low 55%. Inhabitants above 65 years old have only a 25% literacy rate, while the younger generation clearly benefits from a higher standard of education with a 67% literacy rate as seen in figure 4.2. However, the literacy rates are climbing. This is due to an increase in education quality and availability for the younger generations[7].



	TOTAL	MALE	FEMALE	
Literacy rate (%)				
15-24 years	67.2	70.7	64.4	(2015)
15 years and older	50.8	61.8	41.6	(2015)
65 years and older	24.5	39.4	8.6	(2015)

Figure 4.2: Literacy rates from UNESCO[39]

4.4.3 The education system in the Gambia

The Gambian constitution states that basic education is a right and should be free, compulsory, and available to all. The Gambian Education Policy is aligned with UNESCO's sustainable development goal no. 4 of focusing on accessible, equitable, and inclusive quality education for all [40]. However, far from every child in the Gambia gets to attend school. There are usually economical challenges that prohibit parents from sending their children off to school. Even though basic education is free, parents are required to pay for school uniforms and stationery, and by sending their children off for school they reduce the workforce at home. Unicef efforts have been initiated to ensure free school uniforms, bags, and stationary. The government is putting a lot of emphasis on community involvement, whether it being the labor or involvement in decision-making through different community meetings.

The education sector is growing annually, which is becoming a challenge for the government who has to keep up with funding for the ever-increasing need for teachers, classrooms, and other resources. Numbers from the World Bank public sector expenditure review of the Gambia show that the education sector was provided with 2.3% of

the national budget in 2010, and has seen a steady increase to 2.8% in 2015. However, the education sector is funded in large part by private households. In 2015, private households contributed 58% of the total spending on education. This is followed by the government, which accounted for 34%. The education sector also heavily relies on donor contributions, which were equivalent to more than 20% of non-household spending in 2015 according to numbers from the World Bank[44].

4.4.4 Education structure

The educational system consists of 3 main stages. The primary education consists of Lower Basic Education (LBE), education from grade 1 to grade 6, and Upper Basic Education (UBE) grade 7 to 9. The Senior Secondary Education (SSE) is representing grades 10-12 and is less common to finish. Basic Cycle School (BCS) is defined as schools where the LBE and UBE are combined. Children usually begin their education at 7 years old, and if they complete their basic education on schedule, they will graduate their education at 17. It is quite common for a family to only send one or two of their children to school while the others stay at home to work. Some families can't even afford to let their children go past the LBE, because they need to return home to work for their families. Economic challenges in the families often lead to drop-outs, even if only for a year. Failing to pay school fees, drop-outs, and exam failing are all contributing factors to an age span of 12-24 for students attending UBE and SSE[3].

4.4.5 Resources

When studying the context, it quickly became apparent that there are large differences in resources between the schools in the Gambia. Some schools have electricity, printers, wifi, and even computers, while others do not have any of these privileges. This discrepancy is one of the motivations for implementing an accessible, scalable, and understandable visualization of how the different schools compare to each other. Major differences in resources such as desks, teachers, and textbooks do have a significant impact on the quality of teaching and learning. Headmasters at schools can use the

School report card to argue that they need increased funding for resources in order to improve the grades of the students.

There is a very limited amount of technological resources at the school level. About 200 schools have at least one tablet for the teachers to use in the classrooms. How much these tablets are being utilized also varies greatly due to factors like electricity and internet connection. There are schools without any form of electricity, while others rely on power from generators or solar panels. Due to the variance in infrastructure and resources the teachers do not register attendance digitally, but rather send in physical forms to the ministry, who then convert it to data within the information system.

4.4.6 Schools during the pandemic

Schools have been closed for a longer period of time due to the ongoing pandemic. The Ministry of Education has been forced to find alternative methods of teaching, involving technologies such as radio and TV. Furthermore, they have made use of digital tools like WhatsApp and Facebook to facilitate communication between teachers, students, school administrators, and parents[12]. However, due to the gap in resources, some students depend on receiving learning material in physical form which often proves a challenge.

4.5 Stakeholders

Health Information Systems Program
HISP is a global movement initiated to strengthen health information systems in developing countries that originated in South Africa in the 1990s. This goal is largely achieved through their platform DHIS2. The platform is considered an international standard in health information. Potentially covering more than 1.3 billion people with its services, it is appraised as one of the largest and most successful global health information systems and is recognized as a digital public good[41]. HISP at UiO is one of the leading organizations in this movement and contributes with office buildings, im-

plementation support, research, a Ph.D. program, and hosting the core DHIS2 software development team.[41]

HISP West Central Africa

HISP WCA is situated in Togo and is responsible for managing the DHIS2 implementation within the Gambian EMIS. The project related to this thesis has been provided with resources from HISP WCA, as they took the responsibility to import and to some extent process relevant data into the DHIS2 platform. This data was retrieved through their API and utilized in the developed application. Jerry Aziawa is Director of implementations for HISP West And Central Africa, and he acted as the mediator between the project developers and MoBSE. He has experience with the previous solution using MS Access as well as other DHIS2 projects. He was an invaluable resource to us.

Ministry of Basic and Secondary Eduacation

MoBSE is in charge of the management of primary and secondary education in the Gambia. MoBSE operations are managed centrally from their offices in Banjul. Its responsibilities are focused on financial management and the organization is partially decentralized to its six Regional Educational Directorates, which facilitate more effective regional level operations and management[25, p. 6]. Alpha Bah is the Head of EMIS and ICT units for the MoBSE in the Gambia. He has a great responsibility for the management of the Gambian EMIS project.

There are two directorates in MoBSE that have a high level of involvement in the school report card project. The Standard and Quality Assurance Directorate (SQAD) unit is responsible for effective and efficient school management. In relation to the School Report Card, this unit is in charge of the content, metrics, and indicators used in the tool. The Planning Policy Analysis Research and Budgeting Directorate (PPARBD) is responsible for collecting data from all the schools in the Gambia, and performing calculations on these data. This unit is responsible for the design, production, and distribution of the School report card. Any changes made to the report card must be accepted by this unit [16].

Cluster monitors

Cluster Monitors are responsible for monitoring and assisting their assigned cluster of schools. This is achieved by using their knowledge and experience about other schools to provide helpful advice. Furthermore, the cluster monitor is responsible for involving all stakeholders of the schools in the decision-making process. This is achieved by aiding the headteachers in analyzing the school performance data through the school report card, which is presented at the SMC, the School Management Committees.

School Management Committees (SMC)

The SMC is responsible for planning the development for their local school, setting improvement targets, and analyzing and evaluating the progress of these targets. The SMC is also required to distribute information to the PTA and keep a close relation to the headteachers.

Parent-Teacher Association (PTA)

The PTA is a local association consisting of parents of children attending the school, teachers, and pupils of the school. The association was put in place to involve a greater part of the school stakeholders in the decision-making process. This is achieved through close collaboration with the headteachers and the SMC. The PTA will use the School report card to get a solid understanding of the performance and resource status of their school.

Headteachers

Headteachers are responsible for the daily management of the local school. This involves a large variety of tasks such as resource management, staff management, SMC and PTA collaboration, and much more. The headteachers receive help from the cluster monitors in the interpretation of the school report card.

Chapter 5

Methods

This section describes the methods chosen for conducting research, design and product development for this project. The chapter begins with a brief project summary, followed by a description of the research perspective. Finally, the methods for designing, prototyping, and development of the application are described.

5.1 Research method

The research method used for this thesis is selected from the information system research framework presented by Braa and Vigden[5]. This framework depicts a holistic view of the main research methods from the field of IS, and how they relate. Relevant method theory will be described, and this thesis' placement within the IS research framework will be presented.

The information system research framework

Braa and Vigden contributed with a framework to help other IS researchers in navigating the multi-diciplinary space of in context research [5, p.2]. This framework is illustrated in part through figure 5.1. The corners of the triangle represent the intended outcome of the research being; change, prediction or understanding. Should a researcher look to make reliable predictions, a field experiment would be a suitable

research method. However, should the goal be to gain understanding, analyzing a context with an interpretivist case study would be fitting. Finally, if the researcher aims to inflict change in an organization, following the action research method would be a natural choice.

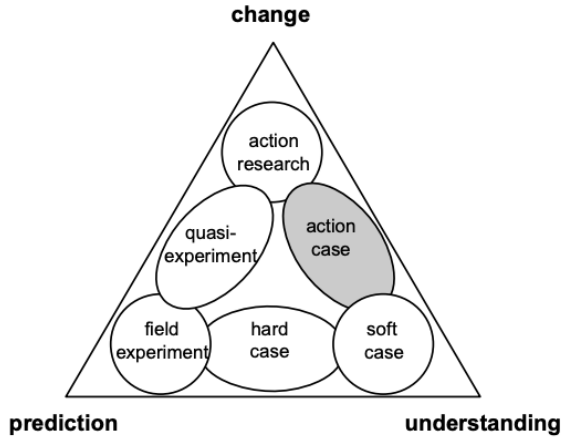


Figure 5.1: IS research methods triangle[5, p.7]

5.1.1 Relevant methods for this thesis

Action research

Action Research is a widely utilized interventionist research method with several definitions. Hult and Lennung describe it as a method used to assist in practical problem solving while expanding scientific knowledge and the process should be conducted with a mutually accepted ethical framework[19, p.247]. The action research process is often described as iterations of a five stage cycle visualised in figure 5.2. These stages are diagnosing, action planning, action taking, evaluating and specifying learning.

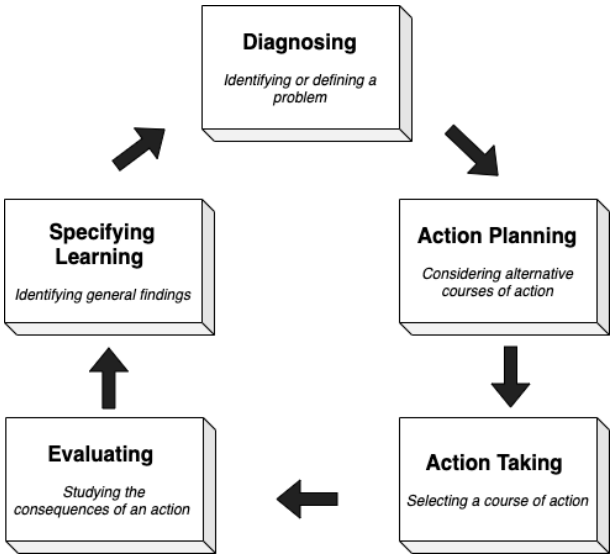


Figure 5.2: AR 5-stage cycle[34, p.14]

The diagnostic stage involves identifying the primary challenges or problems that are the underlying motivation for change in the organisation. This phase will result in a set of hypotheses about the organisation and its challenges[34, p.4].

Action planning is a collaborative effort between practitioners and researchers. The output of this stage is the specification of the organisational actions that should relieve or improve the primary problems found in the previous stage[34, p.4].

In the **action taking stage**, the planned actions are implemented. The practitioners and the researchers collaborate in the active intervention in the target organisation, causing changes to be made[34, p.4].

The **evaluating stage** is then used by the practitioners and researchers to evaluate the outcomes of the actions taken. First they evaluate if the intended change was realised, then they evaluate whether these changes had a relieving effect on the problems[34, p.4].

Specifying learning is known as the final stage of the action research cycle. However specifying learning is often an ongoing process. This stage is about documenting and summarizing the knowledge gained from the AR cycle, and will act as the basis for the

next cycle[34, p.4].

Case study

Benbasat et al. describes a case study as the process of examining a phenomenon in its natural setting, and employing multiple data collection methods to gather information from one or multiple sources[20, p.370] . This phenomenon can be anything from a process, a program, an activity etc.. The boundaries of a case study can often be unclear in the beginning, but throughout the project it will become increasingly apparent.The goal of a case study is to gain an in-depth understanding about the selected case. It can be a useful research method in the study of "why" and "how" research questions, and it is a method best suited for the exploration, classification and hypothesis development stages of the knowledge building process [20, p.371].

Braa and Vidgen found the need to make the distinction between a hard case study and soft case study, due to a variance in focus found in the research literature. A soft case study is considered to be more interpretivist, meaning it has an increased focus in gaining a deep understanding about the case at hand. While a hard case is a more positivist-informed research method, indicating it is also concerned with making accurate predictions [5, p.4].

Action case

Action case is a hybrid research method introduced by Braa and Vigden [5]. It has properties of both intervention and interpretation and can be considered the middle ground between action research and soft case study. Looking at table 5.1, the outcome of an action case is an intended change at a small to medium scale, and a medium level of understanding. These attributes are what places the action case method in the middle of action research and soft case study in figure 5.1.

Braa and Vigden suggests that the action case method is well suited for smaller interventions in a rich context, where the time orientation is shorter than that of a full scale

action research project. Furthermore, it is explained that this method is a great option for new researchers who wish to gain experience of in-context research on a small scale with structured intervention[5, p.15]. These factors indicate that applying the hybrid method action case is a perfect fit for this project.

	(soft) Case study	**Action case**	**Action research**
Change	Unintended	Small/medium scale	Large scale
Prediction	Low	Low	Low
Understanding	High	Medium	Low-medium
Duration	Any	Short to medium	Long
Participation	Low	Medium	High
Time orientation	Historic and contemporary	Contemporary and building future	Building future

Table 5.1: Research method attributes

The process of finding a suitable method

In the beginning of this project we knew that we wanted to make some sort of intervention within the Gambian EMIS. At this point in time we thought that applying the action research method would be the best way forward, and as we gained more insight into the project we started planning our action research cycles. However, after a couple of months we realised that the outcome of this project would be at a smaller scale then that of a traditional action research project. In addition, the project timeline was at a lesser scale, and the project demanded a deep level of understanding of the context obtained by applying several data collection methods. These are all signs that this project should be identified as an action case.

In retrospect, we realize that we did not participate in the original assessment of the problematic situation within the organization, which would be the common practice within action research. Rather, we were invited into and existing process and adopted it as the case was suggested to us by UiO. Some important decisions have been made prior to our introduction to the project, which guided us on to our path. Furthermore,

it is important to notice that this case is a part of a bigger action research project. That project being the collaborative effort between HISP, UiO, HISP WCA and MoBSE to strengthen the Gambia EMIS. The research team for this project has had autonomy in the confined action case and has executed iterative cycles within the time frame and scope of this larger research project.

5.2 AR cycles

Like described in section 5.1, the selected method for this project is action case, a hybrid between action research and case study. In light of this we adopted the AR method of the 5 stage cycle as a part of our research process. In this section we describe the cycles for this project.

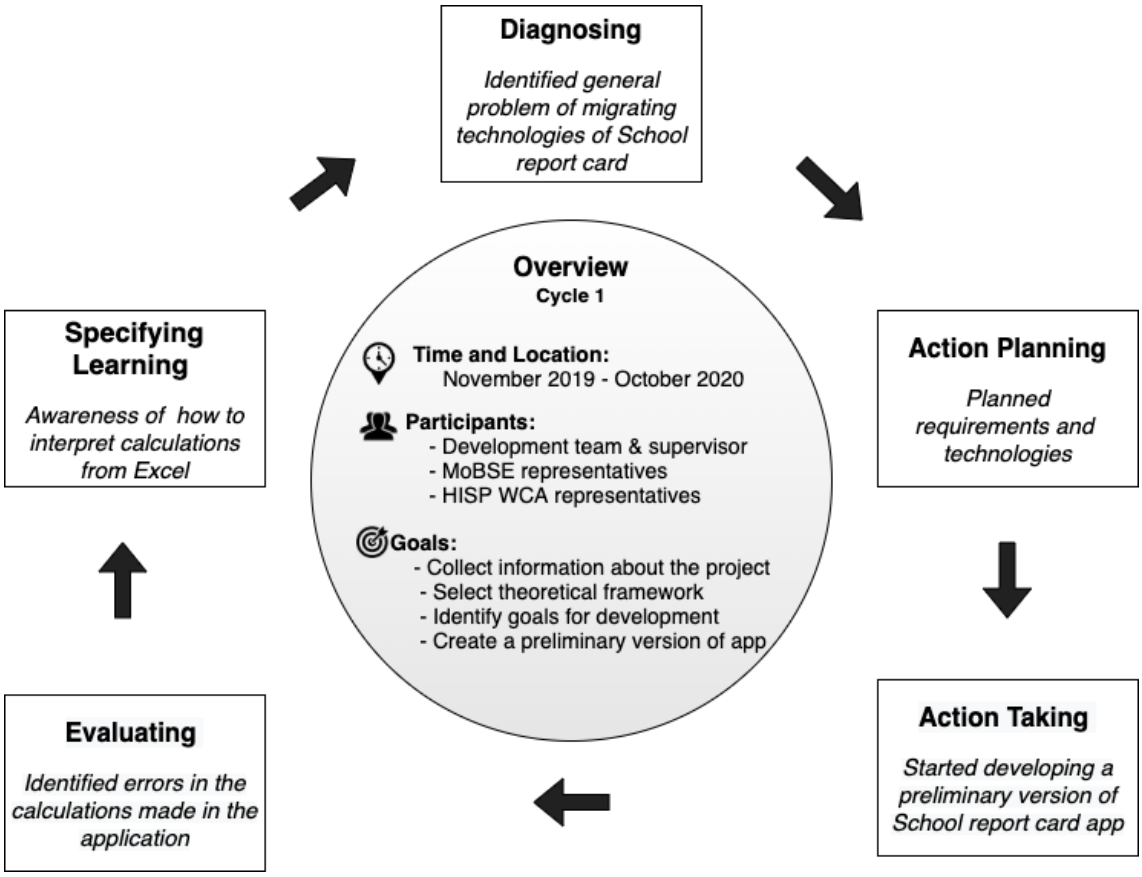


Figure 5.3: Cycle 1 overview

Cycle 1

Visualized in figure 5.3, the first cycle lasted from November 2019 to October 2020. This was the project initiation phase, and was supposed to be partly executed on the ground in the Gambia. In this cycle, the research team first identified the problematic situation through a set of digital meetings with MoBSE and HISP WCA representatives. The product of the first diagnostic stage was the problem which was broadly defined as "a need for migration of technologies and potential re-design of the school report card". An action plan was also developed through these meetings. The first step of the action taking phase was to identify the functional and non-functional requirements of the project, and find suitable technologies to achieve them. This was followed by a preliminary implementation of the ReactJS application within the DHIS2 platform on the Gambian staging server. In the following evaluation phase, the development team

recognised that they had made some incorrect assumptions regarding the School report card calculations and brought these lessons into the next cycle.

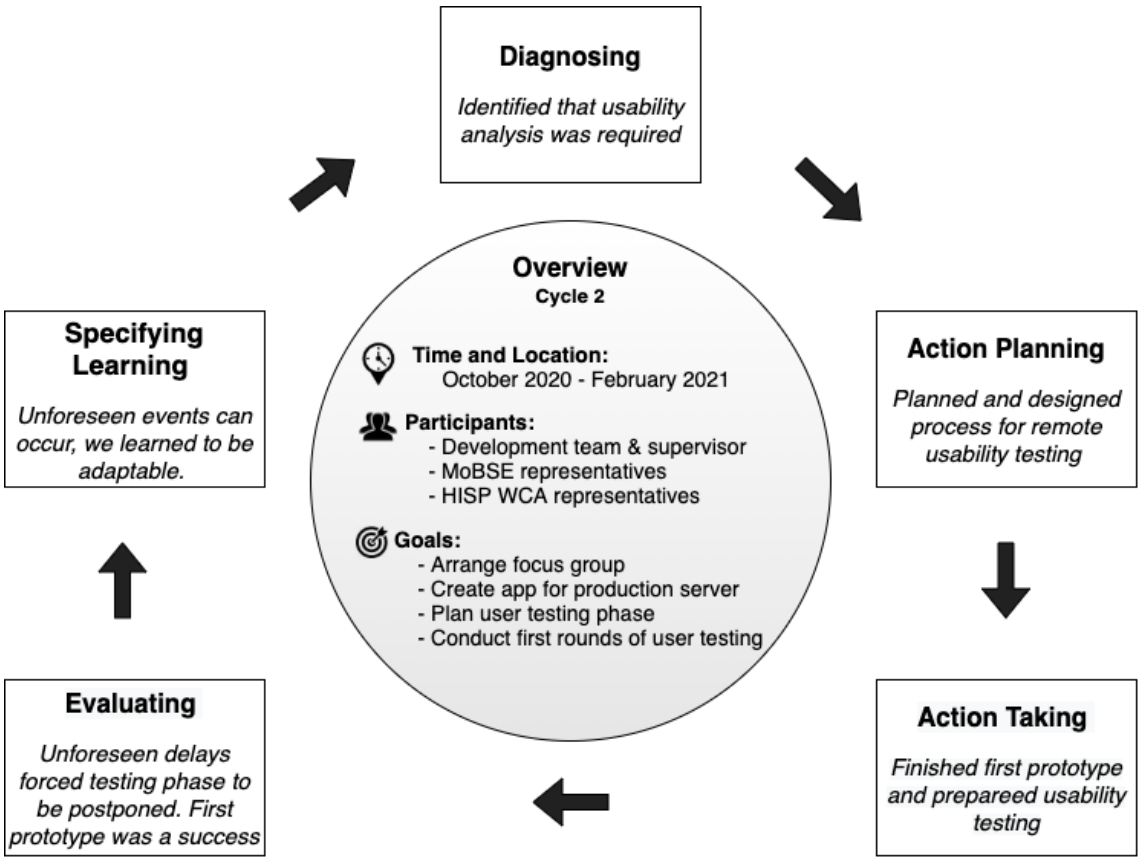


Figure 5.4: Cycle 2 overview

Cycle 2

The second cycle lasted from October 2020 to February 2021, see figure 5.4. Experiences from the specifying learning stage in the previous cycle lay the foundation for this new iteration. The development team recognised that the calculations made in Excel were more advanced than initially assumed, in addition the team identified that due to an increased availability of the tool, a usability analysis would be necessary. A need for more clarification regarding the calculations was identified and planned for. The development team arranged more meetings with HISP WCA and MoBSE representatives in hopes of finishing the mirror solution of the application as a first prototype for usability

testing. The action taking phase of this cycle was to implement a mirror solution and prepare for usability testing of the new School report card published on the Gambian production server. Having learned from the experiences made in the two first cycles, the development team felt comfortable with their approach to solve the problematic situation. However, the goals described in figure 5.4 were not all achieved. Delays due to unforeseen obstacles and events that acted as project bottlenecks. This resulted in the postponement of the initiation of usability testing and focus group.

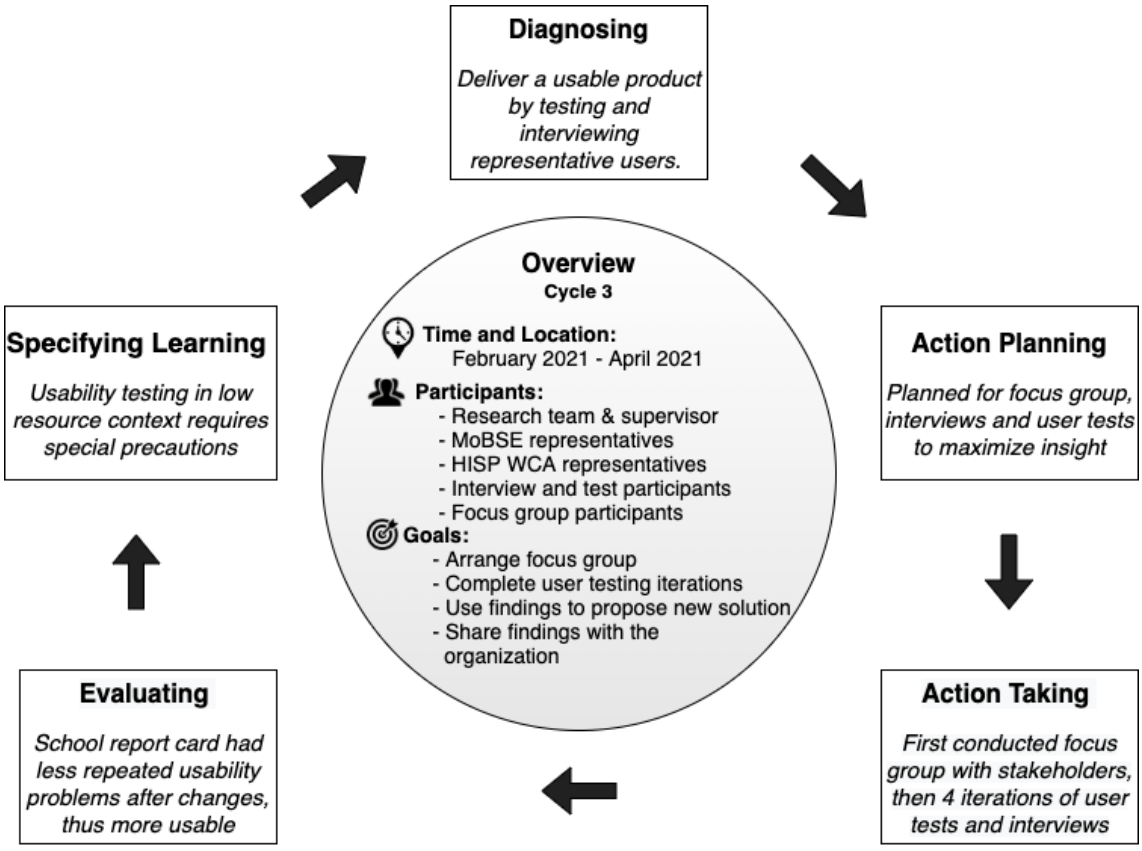


Figure 5.5: Cycle 3 overview

Cycle 3

The final AR cycle for this project was also the shortest one, lasting from February 2021 to April 2021. This cycle can be considered as the main data collection period, as all four usability testing iterations and interviews took place in this cycle, see figure 5.5. This

last diagnostic stage was about using previous lessons learned to achieve the revised goal of performing a usability analysis to deliver a highly usable product to the Gambian EMIS. Due to significant delays in the previous cycle, the focus group and usability testing iterations had to be completed within these last two months. Planning for these data collection methods were a critical part of the action planning stage. At this stage, the project handover was also planned for. The action taking process included the execution of the planned events in addition to updating the advanced prototype as findings were made. The evaluation of this cycle can be considered an evaluation of the entire project and that is described in detail in chapter 7. The findings from the data collection methods were analyzed and sorted into categories. These findings were shared with the MoBSE stakeholders. The lessons learned from this process is shared through theoretical contributions presented in chapter 8 and 9.

5.3 Data collection

In order to collect relevant data for this thesis and the related product development, a set of data collection methods were chosen. These methods include interviews, focus groups, questionnaires and more. Due to the significant limitations related to Covid-19, the data collection process had to be performed remotely. The implications of these limitations will be discussed in this section.

5.3.1 Data collection methods

Action case is the selected research method used for this thesis. As described in section 5.1.1, action case is a hybrid method of case study and action research. Our project was influenced by the fact that case studies utilize multiple data collection methods to analyze a phenomenon in its natural setting. This section will be used to showcase these data collection methods by first defining the methods, then we describe how we implemented them. Table 5.2 displays the frequency and location of the main data collection methods used in this thesis.

Method	Frequency	Location
Focus Group	1	Oslo/Banjul
Semi-structured interviews	20	Oslo/Banjul & Kanifing
Usability tests	20	Oslo/Banjul & Kanifing

Table 5.2: Main data collection methods

Focus group

A focus group is defined by Powell et al. as "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research.". In this qualitative data collection method, the researchers predefined a list of topics that need to be discussed and some goals that have to be accomplished by the end of the meeting. These goals depend on the information the researcher is interested in. The nature of the focus group is somewhat informal and tends to bring out the spontaneous reactions and ideas of the participants. This is achieved by creating an open and interactive environment, but at the same time, the researcher has to redirect the flow of the discussion towards the areas of interest[31].

While reading articles related to the School report card project, we found different motivations and goals, some of which were outdated. To define the main purpose of the solution and better understand each stakeholder's perspective, we found it useful to arrange a focus group. We recruited 5 participants, who we saw as the most relevant stakeholders for this project. This focus group was planned to be conducted prior to the usability testing phase. In this way, the research team would have gained a better impression of the stakeholders' expectations, and the output of this meeting would have helped us develop a more efficient test plan. However, due to the arrangement details being out of our control, the focus group was scheduled to be mid-way during our data collection phase.

Due to strict traveling restrictions, we invited the focus group participants to a Zoom meeting, and each participant attended through their own computer. However, some of them were in the same room since they shared offices. The meeting started with an introduction of all the participants where they stated their current position and expe-

rience with the school report card. All the participants seemed motivated to provide feedback and eager to contribute to improving the current solution.

Interviews

Conducting interviews is one of the most used data collection methods and is applied across many disciplines. They are commonly used to collect and analyze people's opinions, beliefs, experiences, and ideas on relevant topics. The interviewees provide more detailed information, which helps create a better insight into the phenomenon being investigated. [29, p.3].

Interviews can be categorized into three main types: structured, semi-structured, and unstructured. Structured interviews follow a list of predefined questions and have no scope for follow-up questions or variations. This type of interview is relatively easy and quick to conduct and often produces quantitative data. A semi-structured interview is more open compared to a structured interview. It allows the investigator to make follow-up questions based on the user's response. These additional questions can be asked in different ways to different users by keeping in view the desired context. An unstructured interview is more informal and does not follow a designated set of questions. The questions are developed during the interview and based on the responses of the interviewee. Since these interviews are not pre-organized, they tend to be more time-consuming and challenging to administer. This technique is mainly applied when there is no previous knowledge related to the subject or more "in-depth" information is required [29, p.3].

The interview type applied in this thesis is semi-structured. This decision was made due to our limited knowledge of the context and users' experience and expectations of the application. By directing open-ended questions and pursuing the users' ideas in more detail, we were able to gain a better understanding of the context and identify areas of improvement that were not considered before.

On the participants' approval, we recorded the interviews. This allowed us to go back and extract more information when needed. Also, by having the interviews right after the usability testing, we were able to get the users' feedback on the process and make adjustments.

Usability testing

One of the most influential data collection methods used in this research project is usability testing. Due to the COVID-19 restrictions, we could not travel to the Gambia, so we had to perform the process remotely. The intention of the testing process was to generate data about the usability of the tool but turned out to be a valuable source of contextual knowledge as well.

As mentioned in section 2.2, there are two main approaches for remote usability testing, synchronous and asynchronous. After considering the pros and cons of each of approach, and taking into account the nature of our thesis, we decided to use conduct tests synchronously. To ensure we would have all the feedback needed, we dedicated a set time period of one month, from March 1st to April 1st. During this period, we introduced four prototypes in four iterations with a total of 20 participants. A detailed description of this process is provided in chapter 7.

Questionnaires

Questionnaires are a data collection method used to collect information through a series of questions directed to a group of respondents. This group usually comprises heterogeneous and widely scattered groups of people. Depending on the research context, the questions listed on the questionnaire can be open-ended or close-ended. The first type is mainly used to produce qualitative data, whereas the second type tends to produce quantitative data[29, p.5].

The questionnaire applied in this research was paper-based and contained close-ended questions. We ensured that the questions were easy to understand and could be answered within a short amount of time. The questionnaires were handed over to the participants before entering the usability testing laboratory. They contained questions about the participants' digital skills, experience with the School report card, daily usage of digital tools such as PC or smartphone, etc.

After analyzing the results provided by this method, we had a better understanding of the participants' technical experience and what we could expect from other users who have more or less experience than these participants.

Other data collection material

Planning documents/ Guidelines. Data collection plans were handed out to the MoBSE representatives carrying out the organization

Notes were taken during all real time data collection methods. These notes were processed quickly after they were taken and the main findings were discussed in a meeting debrief.

Voice recordings were used for some of the interviews where we knew we would collect pivotal information from important stakeholders, it was also used for the focus group.

Video recordings were used to analyze the usability testing process.

Pictures were taken from the testing laboratory to show how the test organizers set up the room.

Live messaging was used throughout the data collection process. It was both used to quickly clarify topics with MoBSE representatives, and it was used to coordinate the focus group and usability tests. Live messaging also enabled us to quickly inform the test supervisors when they needed to adjust something during tests.

5.3.2 Ethical considerations

An important part of performing research within an organisation is that it has to be conducted with a shared set of ethical rules [19, p.247]. For this project the following ethical considerations were made;

Before conducting interviews and usability tests we provided an informational document describing our motivation for these meetings. The content of the document was described to them in person as well, to ensure that all participants had understood the intention. Furthermore, we stressed that participation was voluntary, and that they should feel free to abort the test at any time if they wanted to. During the usability testing process it was emphasized that we did not want to test the participants, but the product. Participants that evaluated the product were compensated for their travel

expenses and time, at a rate specified by MoBSE representatives.

Every test participant was asked for their permission to record the test for analysis purposes. All footage was discarded two weeks post testing. Any photos taken from the process were asked to be taken, and accepted by the person in the photo.

The research team had an ethical responsibility on behalf of the organisation to ensure that the work that was done was in line with what was agreed, and that the process did not deviate too much from the original plan. Should the research team have failed to do so, the collaboration and partnership with the Gambian EMIS project could have been weakened.

5.3.3 Participants

During this project, a total of 25 participants contributed to the data collection process. Due to the remote nature of this project, the participants had to be selected based on a set of criteria created by the research team. The responsibility of inviting participants was assigned to a trusted contact within MoBSE who had a deep understanding of the project and its stakeholders. Collecting data from a diverse set of participants was a priority for the data collection process. A variance in digital proficiency, experience with the existing solution, gender, age and profession was requested.

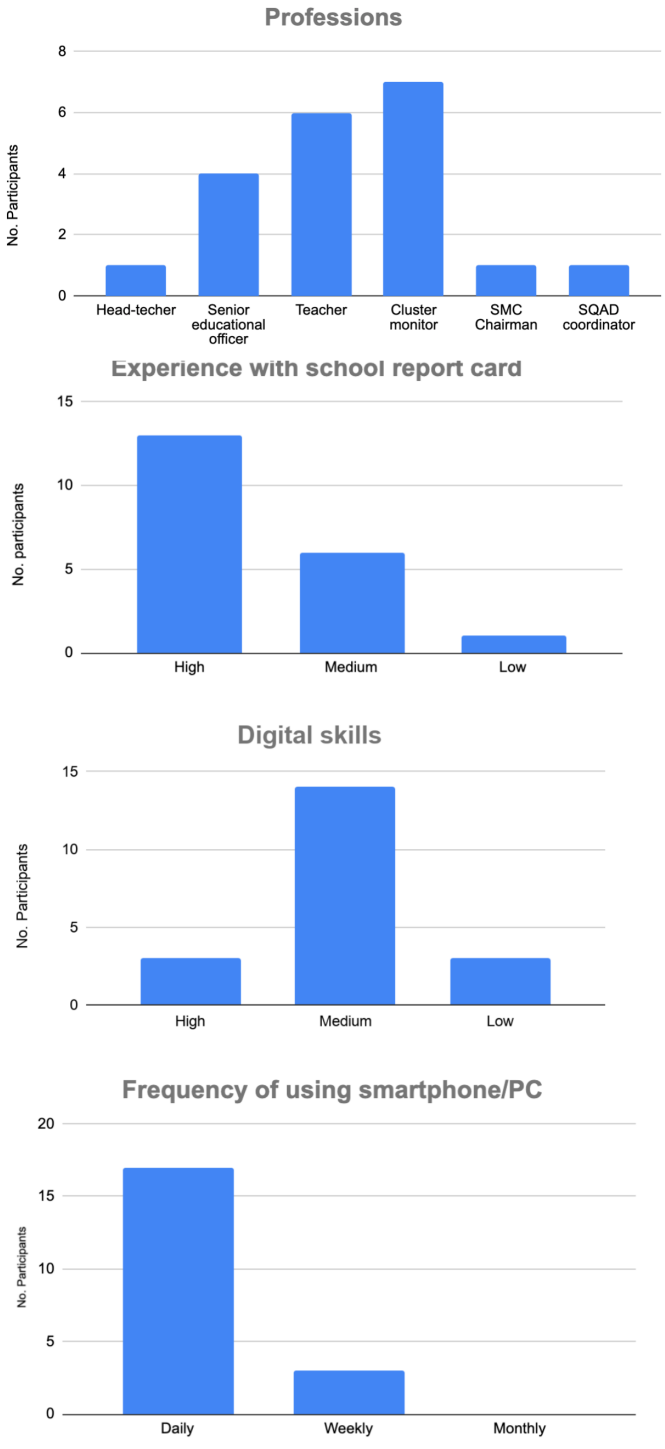


Figure 5.6: Participants

5.3.4 Technologies used for data collection

Through our data collection process we used a combination of technologies used to communicate, record, analyze, and share data. The tools used were selected based on the research teams previous experiences, the preferences of contacts in the Gambia, and an analysis of similar services.

Zoom is a video conference tool that we used for structured interviews, informal interviews, and the focus group. The tool is primarily used for live calls, but we also used the record feature to review the conversations later. This was done with the participants consent, and all content was deleted after two weeks due to privacy reasons.

WhatsApp was used for the arrangement and scheduling of interviews, focus group and usability testing. We used this application since it is the most widespread live messaging tool in the Gambia.

Lookback.io was the primary tool used for conducting remote usability testing. This is an all-in-one testing tool which allows for live conference calls in combination with a share-screen feature. Multiple observers can enter the test without being seen by the test participant, and tests can be stored for later. Again, all content was deleted after two weeks due to privacy reasons.

Google Docs was used to take notes and categorize data for the collection processes. This material was shared using **Google Drive**.

5.3.5 Data analysis

The research team used different methods of analysis to extract meaning from the qualitative data that was collected. The meetings and focus group were organized and conducted by the entire development team, while the interviews and usability tests were conducted by the research team. These sessions were voice recorded and transcribed. In addition, we took individual notes of the topics we found interesting or important during the calls. The processing of this data started with debriefs directly after the

sessions where we compared notes and discussed our findings. Later we processed the rest of the data, and the product was a list of main findings and it often resulted in a new list of questions or topics to look into.

During the usability testing and interviews, we utilized the digital presence of an observer who transcribed the interviews and took careful notes about the behaviour of the users during testing. This qualitative data was analysed using a method introduced by Braun and Clarke named thematic analysis (TA). TA is a flexible six step method for identifying, organizing, finding patterns of meaning within sets of qualitative data[8, p.57]. Our approach was to perform a thematic analysis for each iteration of usability testing and interviews since the feedback was important for the development of the next prototype.

The first step of TA was to familiarize ourselves with all the collected data, reading the data analytically and critically to identify the meaning of it. Then we processed the data and generated some initial codes, a label for a feature of data that might be relevant to answer the research question. This step was followed by looking for themes, a patterned meaning within the data. A quality check was then initialized to review our themes against the codes found. The next phase was to finalize the themes and sort the data by these themes. Our experience was that it quickly became apparent what themes were relevant for us, and that the reviewing phase did not really alter the initial impressions. However, this was our first experience using this process, meaning experienced analysts would probably find many areas of improvement.

The application testing data was analysed with a usability perspective. We made sure to use the design principles of Jordan, and the usability attributes of Nielsen. Since usability was at the core of our interest we chose to further analyze our findings related to this topic. This was done by first collecting all usability findings, then we made note of repeated issues. We also made note of single case issues, and of repeated positive findings. This process is described in more detail in chapter 7.

5.3.6 Data conclusion and limitations

Due to the travel restrictions, we were not able to travel to the Gambia, so all the methods had to be applied remotely. This restriction made it impossible for us to conduct participant observation, a recommended approach from multiple research methodologies. We believe this method would have helped us better understand the context and the users' expectations with the School report card at an earlier stage of the project.

The research team was not able to invite participants first hand, and had to rely on contacts within MoBSE to recruit participants based on the attribute lists provided. The importance of participant recruitment was emphasised, and fortunately our contacts did a great job in finding suitable participants. However this could have proved to be a pitfall for our data quality.

One of the most significant issues experienced in almost every online session we had was the unstable internet connection. On many occasions, the connection was lost, and we had to wait for a considerable amount of time to restore it and resume the conversation where it was left. Also, the participants who struggled with the connection during testing had to repeat themselves multiple times. For obvious reasons, this caused some level of frustration, and it may well have made them modify their answers or refrain from speaking as often as they normally would have.

The focus group was the most challenging method to conduct. Since some of the participants were in the same physical location, we encountered some repeated microphone challenges with echo and noise. Also, the focus group was conducted via Zoom, and the participants had to speak one at a time. Because of these factors, we were not able to have a dynamic interaction and keep the natural flow of the conversation we were aiming for. With this in mind, we decided to send out a form where the participants could share their opinion in detail, and anonymously. This form contained the same main topics we discussed in the meeting, and we sent it out straight away, hoping they would remember the different arguments that had been mentioned in the conference call earlier that day.

In conclusion, the remote nature of the research resulted in many unexpected challenges,

but we adapted our methods to extract the data and contextual information we needed. With more time we would have liked to apply another iteration of usability testing to confirm the changes applied in the final prototype.

Chapter 6

Application development

This chapter presents an overview of the previous School report card and the development process of the web application. This process is divided in two main steps, the mirroring of the previous solution and the usability design improvements.

6.1 The school report card

The School report card is a data visualization and information sharing tool used in the educational system in the Gambia. The tool is managed by MoBSE with funding from the World Bank. It is an important part of the Gambian EMIS and was implemented to support MoBSE's goal of making their decision-making more data-driven. Currently, the digital version of the tool is being used only at the ministry level. Users on the sub-national levels interact only with the paper-based version, which is printed at the request of headteachers responsible for each school. The main objective of the tool is to measure the schools' academic performance in relation to the available resources. This has provided many benefits and found use in several areas of the education sector. By using the School report card in the yearly school performance monitoring meeting, the community's involvement in school monitoring is significantly increased. Before, this process involved only a few education specialists. In these meetings that are usually chaired by SMC, the community discusses among themselves the performance and re-

sources available in the school. The tool is also used to help decision-making at all management levels in the educational hierarchy. The collected data helps increase the accountability for school feeding programs and the payment of SIG[26].

Data collection and processing

The information provided by the School report card serves as a great indicator of the data's impact on the education sector. To achieve the end result that is displayed in the tool, several institutions give their contribution in different phases of data collection and processing. The institution responsible for the School report card in the Gambia is SQAD. They prepare the content, metrics and indicators. Once a year, PPARBD collects the data from every school in the Gambia. When this phase is finished, the data is validated and aggregated. In the end, the PPARBD designs and produces the customized School report card for each school. When the cards are ready, they are distributed to the schools by the Cluster Monitors[26].

Illustrations

As displayed in figure 6.1, the data presented in the tool is visualized using a set of illustrations. These illustrations play a massive role in conveying the information generated in the School report card. Due to the Gambia's high levels of illiteracy, a lot of work has been put into finding the optimal way of visualizing data for a large portion of the population. As a result, the solution uses two different sets of icons to represent the indicators.

Quintiles

Each icon is assigned using quintile classification, falling under three categories: performance, resources, and efficiency. Quintiles have five possible values: 0, 0.25, 0.5, 0.75, and 1, assigned based on the value range of each indicator. The value ranges are defined by the department of School report card in MoBSE and may vary from year to year. Following this method, the schools are broken up into five groups, each containing 20% of the schools[26].

Scorecard structure

An overview of the previous School report card is displayed in figure 6.1. The top left-hand side of the application is dedicated to the user input. Using three dropdowns, the user can select the region, district, and school. After selecting all the required inputs, the data is displayed on the card. A list of infoboxes presents the data related to the schools' resource indicators. These boxes consist of the indicator title, image, and value. More information related to the resources and performance of the selected school is displayed in a table form. In addition to the school data, the table presents information about the region, district, and nation in which this school is located. By having the table in this structure, the users can compare the schools' respective indicators to the district, region, and nation level indicators. The card also displayed the efficiency index for each selected school. This index is used to have an overall evaluation of the performance compared to the allocated resources.

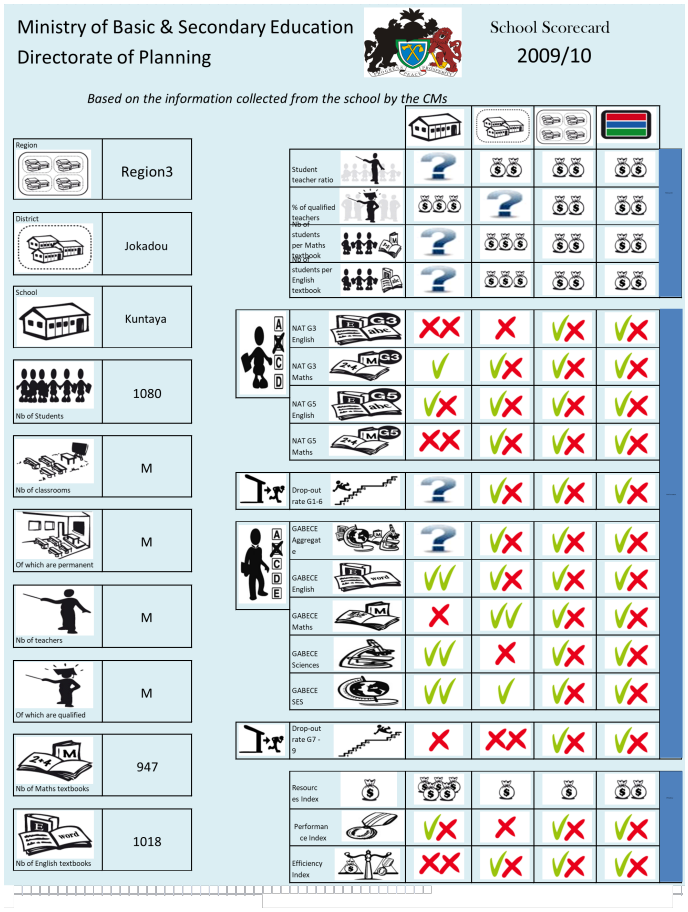


Figure 6.1: School report card

Technology limitations

After years of use, local people have accepted the tool and find great value in using it. It is being actively used at the community level, and has become a staple for the use of data in decision making. However, the current solution is made available using Microsoft Access and Microsoft Excel and the use of these technologies results in several limitations. First, all the instances of the solution are independent and installed locally. All the data has to be inserted manually and this is not always possible due to network access limitations. Having a non-automated process of extraction and insertion raises the chances of having data consistency-related issues. Human errors are very likely to occur and changes made in the main data source or different local nodes will not be reflected on the other instances. As a result, the maintainability of the existing solution is very difficult to handle. The second problem is related to data accessibility. As mentioned in the first point, all the instances are local and the only way to access them is to have access to the machine where the data is stored. Third, as a result of the issues mentioned above, the platform is not suitable for data analysis. The available tools that are widely used nowadays for this purpose can not be applied to the Microsoft applications that the solution is currently using.

6.2 DHIS2 schoolcard

This section presents the development of the DHIS2 School report card. The process is separated into two main parts. The first part consists of the transition of the previous tool into a web application, and the second part focuses on the application's usability improvements.

Step 1: Transition process

As described in the previous chapter, there were several crucial issues with the previous solution. These issues come as a result of using technologies that are not suitable for the purpose behind the School report card. Because of this reason and by the request of the MoBSE, it was decided to transform the School report card into a web application that will be part of the DHIS2 platform. The first step of the development process

was to create a mirror solution of the existing tool, but with a new technology stack. After evaluating the benefits of the most used frameworks and keeping in view the nature of our project, we decided to use technologies such as Javascript, ReactJS, CSS, and HTML. This decision was easier to make after realizing that most of the existing applications in DHIS2 were using the same technologies. By making this transition and deploying the application in the DHIS2 platform, it was able to not only solve the current limitations but at the same time make use of all the benefits provided by the platform.

First, the data consistency problem is easily solved. After collecting all the data in the field, the SQAD team implements it in the dedicated server. This server will be used as the primary data source, and each update made on it is reflected immediately in each instance of the application. Second, each stakeholder provided with the DHIS2 user credentials can access the application online from the DHIS2 platform. This also avoids the need to have the tool locally in each user's machine. Third, the new technologies used to build the application support a wide range of commonly used tools for data analysis purposes. These tools will help decision-makers make accurate comparisons, find areas of improvement, make predictions, etc.

Figure 6.2: Improved School report card

Step 2: Improvement process

The transition of the tool to a web application was not the end of our work. The application was a mirror of the existing School report card, without design or functional

changes. During the web application development, we had many interviews with several stakeholders, who showed us several usability limitations they had encountered while using the previous tool. The design of the School report card was made in 2008, and since then, it was not updated. Also, after deploying the application in the DHIS2 platform, we had to consider the way end users will interact with the tool. Counting these two factors, we decided to take this process a step further by finding and applying usability changes to overcome the occurring limitations.

Since the previous version has been in use for several years, we had to take into account the end-users mental model and prior knowledge but at the same time consider potential changes. In order to find the best balance between these two factors, we applied four iterations of usability testing, which are described in chapter 7. The result of this process is the new design displayed in figure 6.2.

Usability improvements

The improved end product has several design changes. This version supports multiple language, and users can now select the preferred language from the dropdown positioned on the header section. Furthermore, the distinction between the selection area and resources list is made more obvious by using rounded borders. Due to user errors identified during testing, user input can be entered only in a specified sequential order. First, the user must select the region, then the district, and the school. If the user has not chosen the previous required level, the dropdown is deactivated and on hover displays a tooltip that informs the user about the missing input. If the region or the district is changed, the results are removed.

End users can print the results using the "Print" button positioned at the end of the selection area. If the user tries to print without selecting a school, a modal pop up. This modal informs the user about the missing inputs and asks if the user wants to proceed with the printing.

During testing one of the repeated issues was the lack of distinction between two illustrations. This was solved by separated the elements with a thicker border. In order to reduce the complexity of the tool, the data related to resources and performance are illustrated using only one set of icons. Another repeated issue was that users forgot the

meaning of the illustrations. This was solved by adding a visualisation that mapped the icons and the written meaning or value. Finally, the background color used for the table sections was changed to make the text behind it easier to read.

Handover

After building the web application and applying the changes that were decided during the usability testing, the application was deployed to the DHIS2 platform. This marked the end of our contribution to the School report cards, and the source code was handed over to the SQAD. Since SQAD is the institution in charge of the School report card, it will be its responsibility to maintain the application and continue to develop functionalities that will help in school monitoring. To make this transition as easy as possible and help in the process of maintainability, we tried to follow the best coding practices. During the development, big attention was put to writing simple, self-explanatory code. After each development week, the team scheduled a meeting dedicated to code review. In this way, we were able to check each other's code and make improvements. Each method used in the application is followed by comments that describe the method's purpose and arguments. To make better use of React framework and make the code more readable, the code is separated into small, reusable components.

What is remaining for the tool to be used fully?

The extensive use of the School report card is currently limited due to human, material, and financial constraints. The stakeholders do not have previous experience with the DHIS2 platform. To access the application within the platform, they need to be authenticated first by using their credentials and be able to find the application in the list of all the available applications offered by the platform. Also, during the usability testing, we saw that many of them have been using only the paper version of the existing tool and were not competent in using the application. This was a concern also raised during the focus group where several participants mentioned the need for training as a solution to this limitation. Related to the material constraints, the basic tools that are crucial for enhancing the new solution are computers and internet access. In most of the schools in the Gambia, these tools are very limited or not available at all. Thus, they have to use the paper-based version during the PTA meetings. Cluster

monitors are facing the same problem. The availability of laptops and stable internet connection would provide significant help for them during the process of user training and data collection and aggregation. In order to overcome these limitations and provide the resources mentioned above, it is crucial to have financial support from the ministry and other donors.

6.3 Technologies used

React

React is an open-source, declarative, component-based JavaScript library for building fast and interactive user interfaces for web and mobile applications. It is maintained by Facebook and a big community of developers and companies [35]. By requiring less coding and offering more functionalities, React makes it easier to develop dynamic web applications compared to other similar frameworks. Each application can be slip up into multiple components. Components are the building blocks of any React application. They have their own logic and control and can be reused in every part of the application. This helps in reducing the amount of written code and as a result, makes it more readable, simple to manage, and easy to debug.

6.4 Development tools

Git & Github

A major part of the application development process is source code management. When several people are involved in the same project, it is difficult to coordinate the work, stay up to date with others' changes and keep track of different versions of the code. For these issues come in help Git and Github.

"**Git** is a free and open source distributed version control system designed to handle everything from small to very large projects with speed and efficiency" [15]. By using Git, we were able to work on separate tasks without having to worry about overriding

each other's work. Also, Git makes it possible to have the history of all the versions and changes applied to the source code. After using Git, we had to host our repositories in order to be accessible by everyone working on the application. For this we decided to choose Github. Github is a hosting service for web repositories and offers a graphical interface where the users can check all the applied changes, review the code, manage projects and so on. We were able to check each other's work after each commit and give suggestions on how to improve our code.

Trello

To have a clear view of our working process we decided to use a project management tool. Out of many options, Trello was the first to cross our minds since all of us have used it in our previous projects and is free of cost. It is a project management tool that "helps teams work more collaboratively and get more done"[38]. By using Trello we were able to create specific tasks, assign them among us and keep track of any change. Based on the status of the task we created three different tabs: To do, In progress and Done. We made sure to update our tasks status in order to help in our work coordination and have a better of our progress

6.5 Development environment

For our project we decided to use Visual Studio Code (VSCode) as our source code editor. VSCode is a free code editor developed and maintained by Microsoft. It is available for all the biggest operating systems, and it is arguably the most renowned code editor for front-end development. It was ranked the most used development environment tool in Stack Overflows yearly survey in 2019 [28]. What makes VSCode so popular is that it is lightweight, highly customizable, and it supports a multitude of coding languages. Furthermore it has a built in terminal with Git commands, which enables developers to seamlessly update or fetch code from a Github repository. Due to its popularity the extension library of VSCode is comprehensive.

Code structure and development rules

To help us organize our code base we utilized VSCode extensions like ESLint and

Prettier.

ESLint is a linter that is used for "identifying and reporting on patterns found in ECMAScript/JavaScript code, with the goal of making code more consistent and avoiding bugs" [14]. ESLint provides detailed error messages when it identifies errors or weaknesses in our code, which resulted in more efficient development.

Prettier on the other hand is a source code formatter that "removes all original styling and ensures that all outputted code conforms to a consistent style" [32]. When all team members use the same Prettier settings then all spacing, indentation etc. will be uniform. This proved handy to avoid excessive overwriting of code when merging branches in our version control system, which in turn increased the quality of code reviews.

In every development team the developers have different levels of skills and experience with the tools and languages being used. Using a linter and a code formatter enabled us to write more similar code, which in turn increased the overall quality and readability of our code. This is hugely important for the eventual hand off of our project to other developers for maintenance of the application.

Chapter 7

Remote usability testing, prototyping and findings

This chapter aims to describe the usability analysis and improvement process of the School report card in the Gambia. First, the remote usability testing process is described, followed by an overview of the experiences from the four prototyping and test iterations. The final part of this chapter summarizes our findings, limitations, and conclusions for this usability testing process.

7.1 Remote usability testing

Due to the local limitations of the Gambia regarding infrastructure, Wi-Fi connection and stability, PC availability, and a gap in digital proficiency, we found it essential to conduct our remote tests synchronously. However, at a pre-prepared laboratory with a test supervisor, like seen in figure 7.1. To further support this decision, the costs of conducting usability testing in the Gambia are low, and participants do not have to travel far due to the small size of the country.

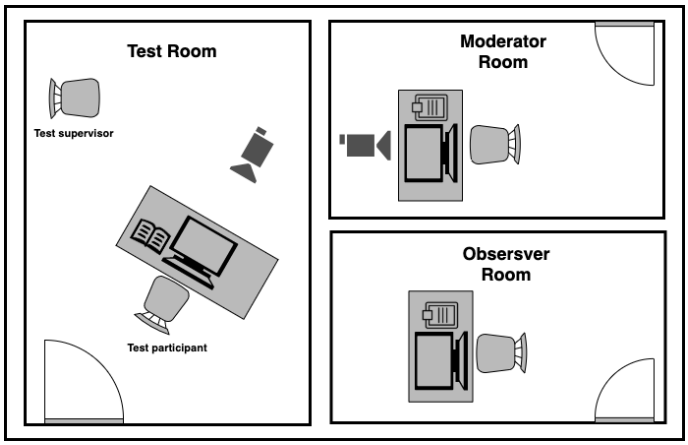


Figure 7.1: Remote usability testing

7.1.1 Test plan

The research team found the need to share a detailed test plan with the MoBSE representatives in charge of organizing the test from the Gambia. This document consisted of a description of what we wanted to achieve and the motivation for initiating this process. It also included a specification of the recruitment attributes we were looking for in the test participants. Furthermore, it described a detailed plan for the execution of the entire test process, the required material, and a role description of the testing supervisor that had to attend all the tests. To ease the complexity of the test supervisor's responsibilities, we wrote a detailed guide of preparations that needed to be made to set up the test laboratory and initiate the testing process. This document also included a detailed schedule showing the list of test dates and the estimated duration for each session.

The test plan described the test structure, setup guide, budget, and schedule of the test process. Furthermore, the document provided some guidelines that instructed the test supervisor on how to act during the tests. First of all, we requested to let the participants deal with the test alone, without the supervisor's assistance. This decision was motivated by two factors. First, the value of our observations would be reduced if the participants received help. Simultaneously we did not want the participants to have a feeling of being carefully watched or analyzed more than necessary. Furthermore, we

made the instruction of only helping the participants with questions related to the test setup that was not related to the actual problem solving within the application.

7.1.2 The test laboratory

The test laboratory was located in MoBSE's offices in the city of Kanifing. The test team linked up with the laboratory digitally, and the tests were conducted with spatial separation. This separation made us produce a detailed list of material requirements and other preparations needed for the laboratory setup. The test supervisor set up the laboratory by following our written instructions. In order to make sure that the test supervisor felt comfortable with the responsibility, we arranged a meeting to discuss the entire test plan in detail and another meeting before the first test. The final result of the physical test laboratory can be seen in figure 7.2.

> "We need a very detailed step by step process that explains what is required of us."
>
> — Test supervisor

As previously mentioned, the research team connected to the test laboratory digitally through the live testing tool; Lookback.io. This tool enabled the test moderator (see section 7.1.3), to share live video with the test participant at the beginning of tests. The tool also allowed for an observer(see section 7.1.4) to attend the virtual test room without being visually present for the participant. This live feed of video is demanding for a stable internet connection. Finally, it allowed us to see a live recording of the participant's screen and actions. Both the test moderator, observer, and participant were separated spatially but synchronized temporally. This structure is illustrated in Figure 8.2.

> "We need to invite the participants to our facilities to ensure stable wi-fi connection during testing. Otherwise I am afraid we will be interrupted."
>
> — MoBSE representative

Figure 7.2: Local test setup

7.1.3 The test administrator/moderator

In usability testing, one of the team members is assigned the role of leading the test. This person is in charge of running the test and is the only person who directly communicates with the test participant. This role is referred to in several different ways in the literature; test moderator, administrator, and experimenter are some examples. We will refer to this role as test moderator. The moderator is expected to have a good understanding of the methods applied during testing and an extensive understanding of the UI because he knows better what to look for and is not surprised or put off by participants' behavior.

In this project, the moderator was a part of the development team that implemented the system, which means that the moderator knew the application exceptionally well. The

research team had a limited amount of experience as test moderators, and we decided that the same person would be assigned this role throughout the entire test process. This decision was motivated by the moderator, who experienced a steep learning curve. We wanted to build on the experiences the moderator had. As the test moderator gained experience, minor alterations in the approach were made to optimize the findings. One example of this would be to ask more open-ended questions to see more interesting behavior from the test participants.

7.1.4 The test observer

In remote synchronous usability testing, it is common to assign the observer's role to one of the team members. The test observer is usually in a separate room and is responsible for analyzing the participant's behavior during testing and makes notes of important quotes. In our project, the observer also noted the extent to which the test participants completed their tasks. These notes included whether they failed or passed a task and whether the participant solved it abnormally fast or slow. The goal of the observer was to take quality notes that made the post-test analysis easy.

7.1.5 The test supervisor

The local limitations mentioned above also revealed the need for a test supervisor, a role assigned to a digital proficient person that would guide the users through the test. This role acts as the mediator between the test team and the participants. The supervisor communicated with the test team before, during, and after testing using WhatsApp. When we assigned this role, we found it essential to find a supervisor that did not have too much ownership over the product. We wanted the test supervisor to be as neutral as possible to prevent them from altering the natural process of the test. Examples of such an alteration could be advising the participants before the test to make them perform well or provide assistance during testing because they are personally invested in accomplishing the task.

7.1.6 Recruiting participants

When recruiting participants for usability testing, we prioritized inviting an even distribution of users for multiple iterations instead of having more test subjects for fewer

iterations. This approach was not random but a carefully selected method that follows the findings from testing literature. It states that conducted more tests with fewer subjects is a better approach to identify usability problems [23]. This finding is also in line with Gould and Lewis' method of iterative prototyping. Looking at the conclusion from an article written by Nielsen, we can see in figure 7.3 that by recruiting only five users, one can expect 80% of the usability problems to be identified [27].

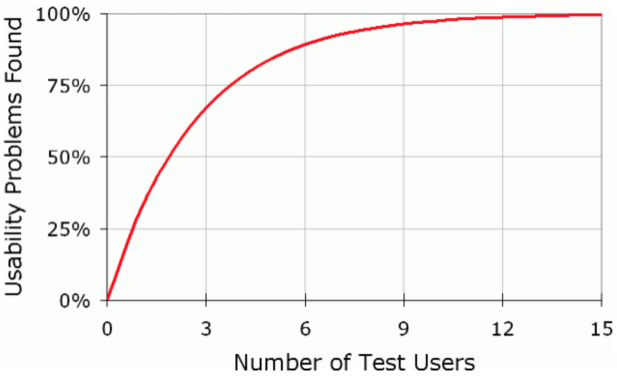


Figure 7.3: Problem identification graph from [27, p.156]

To further support this approach, a cost analysis from Usability Engineering also suggests that the cost-benefit in relation to the number of users rapidly declines after five users, as seen in figure 7.4. In fact, the budget for the entire test process resulted in the total cost of below 700$USD. However, this budget does not consider the costs for MoBSE who shared facilities and work force for the role of test supervisor.

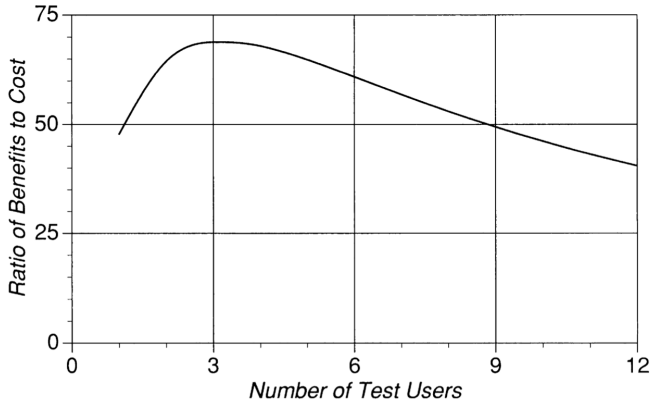


Figure 7.4: Benefit cost ratio[21, p.174]

The recruiting of participants was performed by one of the representatives from MoBSE who had a unique combination of knowledge of the potential end-users of this new product and the user base using the previous version of the School Report Card. As mentioned in chapter 5, Methods, we requested users with the various traits listed below.

- Digital proficiency
- Experience with the existing solution
- Education and Literacy
- End-user group
- Sex
- Age

> "Traveling distance is not a problem. The Gambia is a very small country, and people will likely accept and invite to the big city when expenses are covered. In addition, people want to contribute to the community"
>
> – MoBSE representative

However, there was one exception to this style of recruitment. In the very first iteration, we recruited expert users who were familiar with the previous product. We wanted to conduct the first iteration with expert users to get a good impression of how the tool translated from an excel spreadsheet to a web application. Novice users were first introduced in the second iteration after we had made some initial changes.

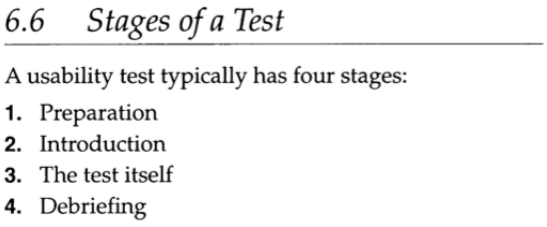
7.2 The testing process

The testing process started after the initial migration of technologies was completed. As previously explained, this was a mirror solution to the previous excel product and acted

as the initial prototype to be tested. To start the testing process, we conducted a pilot test, followed by four usability test iterations. The conclusion of this testing process was a final delivery of the new system and a report that highlighted the strengths and weaknesses of the system.

Before testing the application with potential end-users, a pilot test was conducted exclusively with the research team. The pilot test was executed to uncover any potential pitfalls during testing and estimate the time needed to conduct the test for each participant. It was also used to see if such a test could unveil application limitations before the participants got to interact with the product. The pilot test was set up by following the descriptions in the test plan we had created. After the initial setup, we used our testing software of choice, Lookback.io, and pretended to be a test administrator and participant. The outcome of this pilot test was increased confidence in our testing software and a more elaborate test guide with a detailed step-by-step guide on how to use Lookback. In addition, we got a better estimate for the length of the tests and developed some hypotheses about what parts of the system the participants would struggle to understand.

The official usability testing process started on the 1st of March and lasted for one month, till the 1st of April. During this period, we conducted four iterations. In the first iteration, we presented the mirror solution of the existing tool. Each other iteration was used to test an improved prototype build upon the feedback received from the previous iteration. Five participants tested each prototype, as described in section 7.1.6. Each of these tests followed the test structure described by Nielsen in figure 7.5, except for an additional interview at the end. This interview was our chance to get an even more detailed picture of the tool and the context.



6.6 Stages of a Test

A usability test typically has four stages:

1. Preparation
2. Introduction
3. The test itself
4. Debriefing

Figure 7.5: Stages of testing, [21]

To identify users' major misconceptions and better understand their actions, we decided to apply the thinking aloud method. According to Nielsen, this is one of the most important usability engineering methods. Implementing the thinking aloud process involves the continuous verbalization of thoughts while users are interacting with a system. It is a method borrowed from psychology, which has proved to increase insight into a subject's thought process. This benefit has been transferred to the testing of user interfaces. A downside to this method is that it can put much weight on the users' perception of what went wrong and how they could fix it. The final and hugely important step after each testing iteration was the analysis of the generated data. This data was categorized into five main themes described in the methods chapter (5). These findings were sorted, and potential solutions were discussed within the research team before selected and implemented.

7.3 Prototyping and usability design

In the Usability Engineering book, Nielsen states that usability is measurable and can be tested through prototypes or final products. Because of this and based on the principles defined by Gould and Lewis, iterative design and empirical measurements, we decided to apply the usability testing process by using prototypes. We conducted four usability testing iterations during the period 1st March - 1st April, where we tested one new prototype per iteration.

The structure of each iteration was the same. The first step was to categorize and analyze the collected findings from the previous iteration. We mainly attended usability-related issues and only made notes of other findings in order to represent them to SQAD at a later time. This was followed by a brainstorming session resulting in several possible solutions for each issue. After selecting the best alternative, we started implementing the changes on a new prototype which was tested on the usability testing session.

In the next section, we present a brief description of each iteration by introducing the main findings, issues, and solutions. Tables 7.1, 7.2, 7.3, 7.4 presented at the end of

each iteration section, give an overview of all these findings. Also, we explain why we made a specific decision and the usability design principles that we have applied.

7.3.1 Test iteration one

The first prototype was the result of the joint effort by the entire development team. This initial prototype, presented on figure 7.6, was tested on the 1st of March and was a mirror solution of the existing tool. Our aim was to use this prototype to analyze how well the tool transferred from an excel sheet to a web application.

In this iteration, we introduced for the first time the thinking aloud method. We explained it quite formally by defining it as a common method used when testing applications, and the motivation for using it was to increase our insight into their thought process. After this explanation, the users seemed worried. Some were probably worried because the process sounded very professional, and it was something they could potentially screw up, while others were concerned that it might reveal their lack of expertise in the product. Luckily, we identified this reoccurring problem at the iteration debrief and planned for a less formal approach for future iterations. This proved to be a good adjustment, as the rest of the test users seemed quite understandable when introducing the concept in later iterations. When the users knew what to do, they usually always managed to express their reasoning behind their thoughts. However, when a task was challenging, we quite often had to remind them to think aloud. This reminder was usually enough to remember it throughout the remainder of the test.

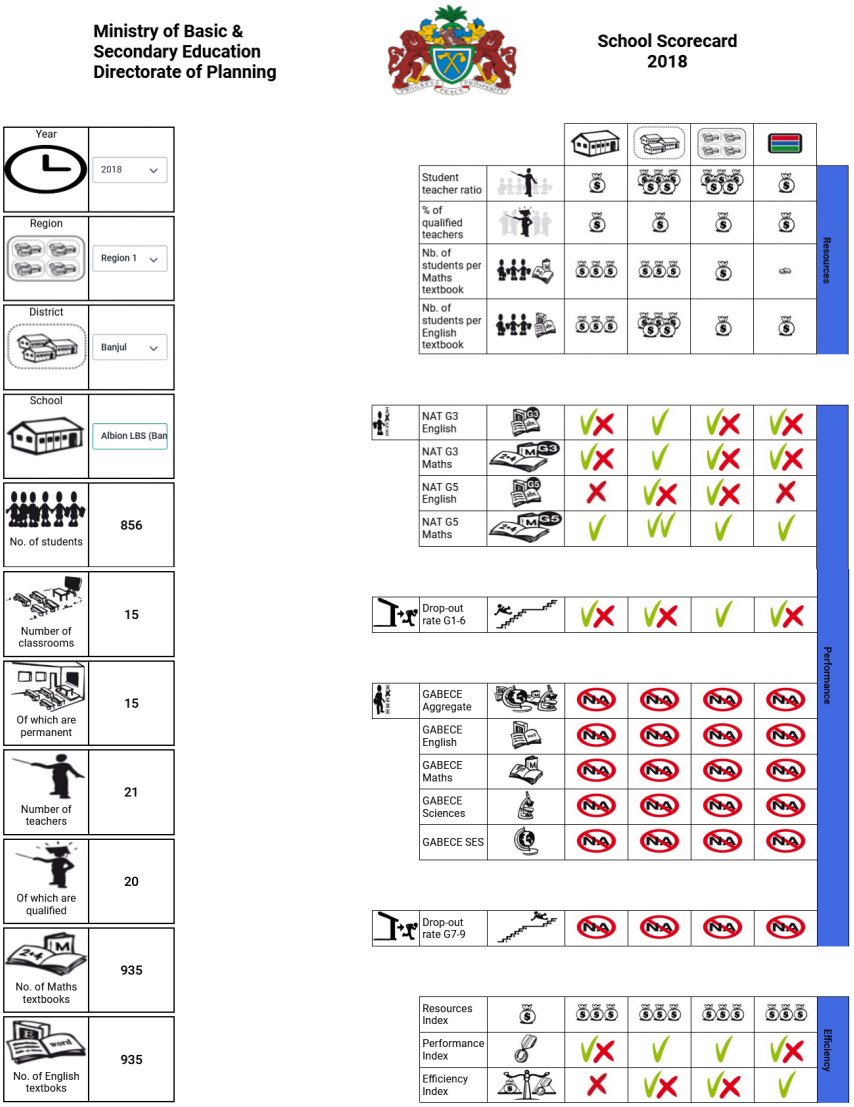


Figure 7.6: First prototype

Since it was the first time we tested the tool, the first prototype introduced many new findings related to usability, data visualization, and the usability testing process itself. The first limitation we detected was related to the printing functionality. Even though most users interact with the paper-based version of the tool, and printing is a commonly used functionality, the previous solution did not have a dedicated print button. Thus, users could only print using the keyboard shortcut or by clicking the right mouse button and then selecting print. When the users were asked to print the results, none of them used the shortcut, and only the ones with previous printing experience managed to

perform the task.

While asking the participants to describe the displayed results after selecting a school, we noticed that some of them had difficulties understanding certain illustrations even though being expert users. When asked for their opinion of how this problem could be solved, the users requested additional text on the tool to explain the meaning of the illustrations.

> "Sometimes I find it difficult to remember what a specific illustration represents. It would be really helpful to have some text describing them."
>
> — Participant 3

Another repeated issue was related to the table's structure presenting the resource indexes. The users were confused about which illustration referred to the school, district, and nation level.

Solutions to previous issues	**New findings**
1. Transition of the excel version to a web application part of the DHIS2.	1. The users have difficulties printing the results. 2. In some cases, the users have to scroll for a long time to find their school. 3. Some users are confused about what illustration refers to the school, district, nation level in the resources index.

Table 7.1: Iteration one summary table

7.3.2 Test iteration two

The first step was to analyze the collected data from the first iteration. We categorized the findings as described in section 5.3.5 and started to discuss potential solutions. Our decisions on usability improvements were based on usability design characteristics defined by Jordan P.W. After deciding how to solve the issues found on the previous prototype, we started to develop the second one.

To make it easier for the users to print the results, we added a print button. Considering the users' expectations based on their knowledge of other similar applications, we placed the button on the top right-hand corner of the header. This approach complies with the compatibility principle defined by Jordan. The print button also contained a print icon to help illiterate users understand the functionality.

Related to the issue with the table structure, we faced some limitations. An optimal solution for this case would be to change the image representing the resource index. While discussing this option with the SQAD representatives, they stated that SQAD had identified the outdated illustrations and they would address this issue at a later time. Thus, we started to look for other solutions and decided to apply a thicker border that would highlight the separation between the row titles and the results. This border would help users to read quickly and easily without causing confusion. We made this decision considering visual clarity principle.

In addition to the changes related to the issues found in the previous iteration, we applied some usability improvements. While testing the application ourselves, we saw that some districts had a large number of schools. If the user wanted to select a school placed at the end of the list, it was needed to scroll for a considerable amount of time. To solve this usability limitation, as shown on figure 7.7, we changed the school dropdown with an autocomplete input field. By using this advanced element, the users could filter the long list by typing the characters of the school they wanted to select.

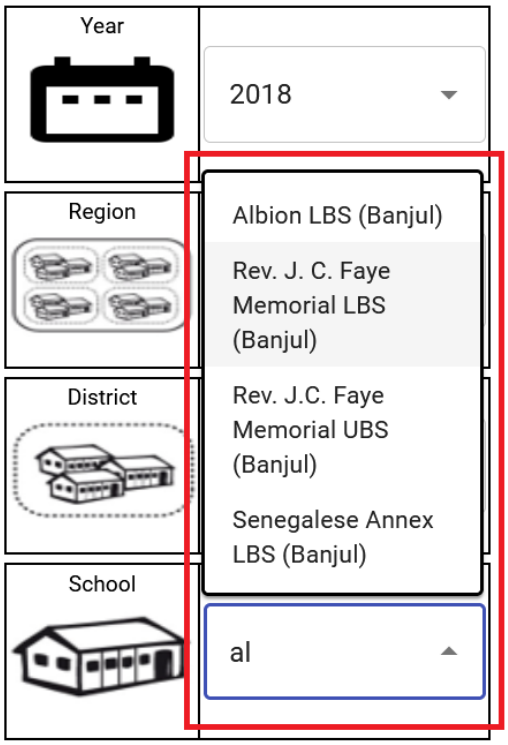


Figure 7.7: Autocomplete

After finishing the prototype, we conducted the second usability testing session. Unlike the first session, the second prototype got tested by users with various experiences with the previous tool, who represented a more accurate picture of the end-user groups. This helped us identify additional areas of improvement.

Even though we followed the compatibility principle for positioning the print button, when users were asked to print the results, they had difficulties finding it since their focus was only on the scorecard they recognised. Also some users struggled on finding the input area where they could select the region, district and school. Obviously, we had to move the button to another area where the users could easily detect it and make some adjustments on the input section.

The replacement of the dropdown with autocomplete input did not work as we assumed. Most of the participants had difficulties using it. Some of them were expecting to have

a pre-filled list of all the available schools without providing any input.

> "The dropdown does not seem to work. I am clicking on it and no values are being displayed."
>
> — Participant 7

Others, after spending some time understanding the input field, usually added only one character to the text field, which didn't have too much of an effect of the overall time spent on this input element.

Solutions to previous issues	**New findings**
1. Dedicated print button. 2. Autocomplete input for school selection. 3. Increased border weight.	1. The users can not locate the print button 2. The selection area can be difficult to find. 3. Autocomplete input does reduce the time spent on the school selection and is complicated to use for some users. 4. The text seems to be a bit too small to read.

Table 7.2: Iteration two summary table

7.3.3 Test iteration three

Same as in the previous iteration, the first step was to analyze the findings from the previous cycle, and discuss potential solutions. The first issue we addressed was the input section. To make a clearer distinction between the selection elements and the data in the resource boxes, we decided to apply round borders on the input boxes. In

our opinion, this issue was related to the misuse of the consistency principle. Since two different functionalities, user input and resource data presentation, were displayed using the same layout, the difference between the two sections was not obvious.

Related to the print button position issue, we decided to move it to the end of the input section. Since the user would interact with this section, it would be easier to detect the button. Another reason why this position is more suitable is that the printing functionality is most commonly used after the school selection is made. A new functionality added to the print button was input validation. If one of the required levels is missing, the user is prompt with a modal. As presented in figure 7.8, this modal informs the user about the missing input and asks if he wants to proceed with the printing.

Since the participants from iteration two did not reduce the time spent on the input fields by adding autocomplete input fields, we decided to revert to the original solution. In order to minimize the possibility of user errors, we disabled the dropdowns when the previous required level was not provided. When the user would try to click on the disabled element, a tooltip would inform the user regarding the missing input. By following this approach, the information can be read quickly and easily and avoids potential confusion. This decision was made based on the principles of error prevention and recovery, visual clarity and feedback.

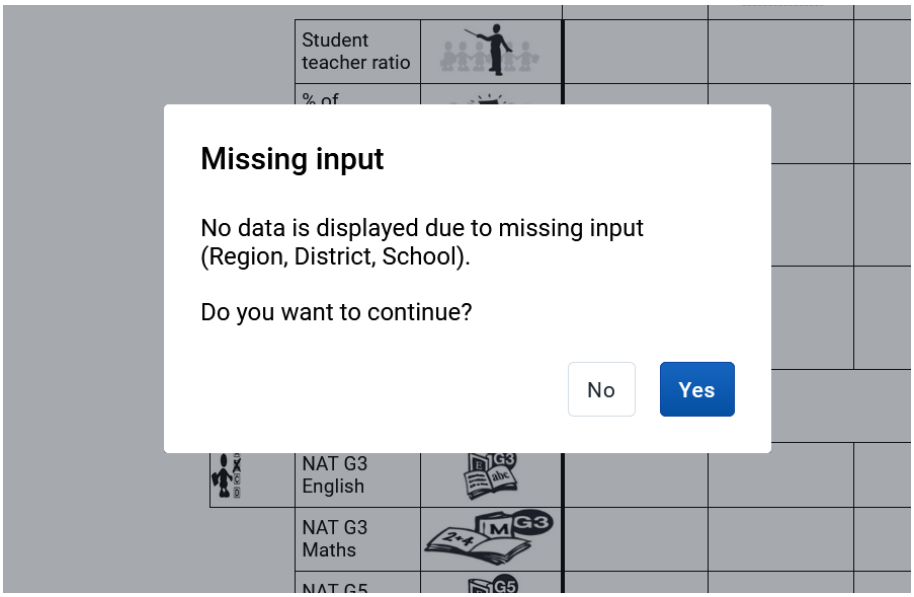


Figure 7.8: Input validation modal

All these changes were applied to the prototype used on the third usability testing. At the end of this session, we were very happy with the feedback that we received. The changes that we made worked as we intended.

None of the users showed difficulties in identifying the input section. After reading the tasks, they provided the input right away. One user tried to enter the school without choosing the region and district first, but he immediately selected them after reading the tooltip info. To test this functionality on the other users, we created some additional use cases which forced the participants to use the disabled dropdowns. All of them were able to explain why the dropdowns were disabled and how to activate them.

Related to the print button, it seemed like the new position was the right one. All the users were able to print the results when asked. Since none of them tried to print without selecting the school, we had to create some use cases to test the validation modal. The users understood the presented information and had no difficulties interacting with the modal.

The main issue found in this session was related to the illustrations. Same as in the first iteration, some users did not seem determined while explaining the meaning of the

images. When asked about their opinion on possible improvements for this issue, they all approved the idea of including a description map as well as a new set of illustrations. This map would present the meaning of all the illustrations used on the application.

> "The description table and the use of only one set of icons would help both the experienced and the inexperienced users."
>
> — Participant 11

At the end of this session, we came across an interesting finding. One of the participants mentioned that the school report card is distributed in different languages depending on what communities it is sent to. After presenting this finding to the SQAD representatives, they confirmed that the medium of communication is usually the local language spoken by the majority of the participants in those meetings. This is because many parents and community representatives are uneducated, especially in rural areas.

Solutions to previous issues	**New findings**
1. Move the print button to the end of the selection area and add input validation on print click. 2. Add round borders to the selection sections. 3. Revert the school selection to the original solution. 4. Increase the font size	1. The users have difficulties understanding the illustrations' value. 2. Some users do not understand the year icon. 3. Some users express the need for a map to describe the symbols' value. 4. Multiple languages can be used on report card meetings.

Table 7.3: Iteration three summary table

7.3.4 Test iteration four

In this iteration, the list of repeated issues was significantly shorter. Based on the success of the changes applied to the third prototype, we decided to put our focus on the illustration issue and language options.

After a brainstorming session related to the illustrations, we came up with several possible improvements. The first and most obvious option was to change the set of icons. Still, as explained in the second iteration, the SQAD had put a lot of effort into the selected images, and they were happy with their icon selection. So we had to find another alternative.

Instead of using two different sets of icons to present the results, we decided to use only one of them. This approach would help in the users' learning process and reduce their training time. The selection of the icons that we had to use was an easy decision. Based on the previous feedback from the users, we knew that the moneybag icons were more intuitive for them and we decided to remove the ticket set of icons.

To guarantee that users without training could understand the illustrations, we added a description map at the bottom of the results table. This position was chosen considering the compatibility principle described in iteration two. As shown on figure 7.9, we used an arrow directed from the worst result to the best to make the map understandable even for illiterate users.

Figure 7.9: Illustrations map

Related to the language finding, we decided to add a dropdown containing the main languages used in the Gambia. Based on the compatibility principle described in iteration two, this dropdown was placed on the top right-hand corner of the header. However,

due to time limitations, we implemented this element only for test purposes, and it was not functional. The language change on the dropdown would not reflect any change in the content.

These changes were applied to the fourth and last prototype that we developed. This usability testing iteration also marked the end of our data collection process.

After finishing the session, we found it very interesting that none of the participants mentioned the removal of the ticket icons. They did not show any confusion explaining the results of the performance and resources even though they were displayed by the same set of icons. Related to the language selector, some users were not able to find it. The same happened for the illustrations map. Even though we advised them to check the whole layout of the application before reading the tasks, many of them did not scroll till the end of the page. In our opinion, this problem is related to the users' mental model.

> "I don't think this application has language options."
>
> — Participant 13

Since users were familiar with the previous version of the tool, they did not understand that there was a description section available or if they should look for it. Also, two of the participants did not understand the map's description.

In this session, we re-encountered the scrolling issue in the input fields. Two participants had to scroll for a while to find their schools. However, in the second iteration, we concluded that this way of presenting the list was the easiest for them to use.

Solutions to previous issues	New findings
1. Display only one set of icons. 2. Change the year icon. 3. Add a description map for the illustrations. 4. Add language options.	1. Some users have difficulties finding the language selector. 2. Some users have difficulties finding and understanding the illustrations' description map.

Table 7.4: Iteration four summary table

7.4 Usability testing process summary and findings

In this section, we present the limitations encountered during the usability testing, followed by a brief summary of the process.

Limitations

Throughout this project we decided to perform between-subject testing, a test method where one participant only tests one version of the application. This is considered the most valid, but has some downsides [21, p.178]. For example, we lost the opportunity to get comparative feedback. If a user had tested two versions of the system, they could point to which version they liked better which could have resulted in some valuable feedback.

Coming into this research project, the test team had limited experience with usability testing. Experienced testers who plan well and implement good methodologies will on average find twice as many problems with a UI than inexperienced testers[21, p.79]. We can relate to this, as we felt we learned a lot during the process. Either way, the literature agrees that some testing is always better than no testing.

In usability testing it is generally not recommended that the test team is composed

solely of developers, or people who have close ownership to the product. This is because they often can explain away problems rather than acknowledging them[21, p.181].

There is a weakness in organising each iteration for only 5 users. In our case, the test participants had vastly different levels of digital proficiency and literacy. This variance of said traits could have resulted in test iterations full of participants with either very low or very high levels of digital proficiency and literacy, which could negatively affect the test results that were analysed and effected decisions made for future prototypes.

Conclusion

	Iteration 1	**Iteration 2**	**Iteration 3**	**Iteration 4**
Repeated issue	7	6	4	1
Single case issue	2	3	2	1

Table 7.5: Usability issues

Due to the Gambia's local limitations, we had to conduct the remote usability testing synchronously and in a pre-prepared laboratory. Prior to the testing date, we performed a pilot test to uncover any potential pitfalls during the main process and estimate the time needed to complete the test for each participant. Continuous communication with the supervisor and a detailed testing plan was crucial for the success of the process.

The development of four prototypes based on the users' feedback helped us identify and solve many issues detected throughout the usability testing process. Our focus was mainly directed to the repeated issues since they would affect most of the end-users. However, during the process, we identified some single case issues which were important to address. An example of this is the case where we discovered that the school report card should be available for multiple languages.

As presented in table 7.5, the first prototype contains a considerable number of usability issues, but on each following prototype, this number was reduced. As a result, in the last prototype, we found only two usability issues, which in our opinion, are related to the users' mental model of the previous version of the tool. These numbers can be used to measure and reflect the usability improvements applied on the School report card.

Chapter 8

Discussion and Analysis

This chapter analyzes and discusses our process and findings in relation to the selected theory presented in chapters two and three. The chapter is separated into two main sections answering the research questions of this thesis:

RQ 1: What are the factors to consider while developing for usability in low resource context?

RQ 2 : How can remote usability testing be used as a usability evaluation method within a low resource context?

Each section starts with the introduction of the main concept of the research question, followed by a description of the factors that guided our process and how they were applied in our case. In the end, we discuss the findings that can be used by the general audience interested in developing or conducting research in similar contexts like ours.

8.1 Usability

The main focus of this thesis was designing for usability within a low resource context. Even though the usability definitions in chapter 2 are quite different, they all emphasize in some way that usability is a term used to define how effectively a user can interact with the system within a specific context. Thus, usability is a crucial factor in the design and development of any application, and maybe especially so within low resource contexts. A key factor for this project when designing and developing for usability was user involvement. Our goal was to ensure that the application was usable for the vast array of potential end-users who could now interact with the digital solution and not only with the paper-based version.

The development and design of the prototypes for the School report card were guided by the usability attributes defined by Nielsen. In order to achieve these attributes, we filtered out and applied a set of usability design principles suggested by Jordan. In addition to this, we took into consideration the contextual concerns discussed by Li, to build on his experiences when developing for usability in low resource contexts. After applying this combination of literature in our usability improvement process, we came up with a set of recommendations that can be used while developing for usability in low resource contexts.

8.1.1 Usability obstacles on low resource contexts

Li M. refers to three main obstacles while developing for usability in low resource contexts. This section gives a brief introduction of these obstacles, followed by their impact on our usability improvement process.

Constraints introduced by legacy design. While developing a new version of the system or transitioning from analog to digital, the developers must find a balance between the use of familiar concepts and the implementation of new design structures. The school report card has been in use for several years, so we had to take into account the end-users mental model and prior knowledge. The users have been trained based on

the current version of the tool. Major changes would confuse them, require additional training for existing users, and as a result, reduce their interest in the tool. Because of these reasons and after discussing the case with SQAD representatives, we decided not to change the main data visualization structure of the School report card.

This decision had major implications for the design of the revised School report card and had a significant impact on the usability improvement process. To keep the layout familiar for the existing users, we had to exclude some functionalities that we originally had planned to implement, for example, the implementation of more advanced data structures such as graphs. However, at the end of the usability testing process, we can say that for the Gambian context, this was the right decision. Even though the structural changes we implemented were not of big scale, we noticed that even smaller changes confused the existing users who had used the School report card previously. This confusion was likely due to the users expecting the system to be designed in a specific way. Larger scale changes could require a re-learning process of the tool and a change of the users' mental model.

Scale and heterogeneity of user groups. Generic software needs to be customized in order to be more specific and usable according to their intended users and their context. The School report card is developed to be used by a wide range of users who have vast differences in their literacy and digital proficiency levels. Since the Gambia has a high level of illiteracy, we put a lot of work into finding the optimal way of visualizing the results and finding the right input elements. MoBSE representatives shared their experiences with us, as they were accustomed to using specific approaches to make products usable for the illiterate population. By following a user-centered design approach, we were able to test many options and select the most suited changes based on the users' feedback in combination with the usability analysis performed by the test team.

Constraints introduced by software. Most of the software is off-the-shelf and is not built specifically for the implementation's use-case. Even though we made the School report card part of the DHIS2, the app was not dependent on the platform's functionalities. Thus, we did not face this type of constraint during this period. However, the goal of the School report card is to spread to other African countries to support data-driven

decision-making in educational systems. Since the tool was developed specifically for the Gambian context, the developers will need to make customization in order to make the application usable for their use cases. Other countries that have not yet started to use such a data-driven decision-making tool might want to start the design process from scratch, as they are not limited by the mental models of existing users.

8.1.2 Usability attributes

Nielsen defines five main usability attributes, presented in chapter 3. These attributes, combined with the user feedback, helped us with the decision-making during the usability improvement process.

Learnability refers to how easy the application is to learn so the users can start using it in a short amount of time. After completing the usability testing process, we can say that users had no difficulties understanding the required input and how to interact with it. On the other hand, the result interpretation is more challenging. Some users have difficulties understanding the set of icons representing the results. However, by using only one set of icons and presenting the illustrations' description map, the users need less time to learn their meaning. As a result, we think that the training period is still required, but this period can be reduced by introducing the improved version of the tool.

Efficiency indicates the level of users' productivity after learning how to use the application. We would argue that the improvements made in the input elements and data illustration have increased the application efficiency. Even though we could not test the application in the open-world, when users revisited the application during the testing process, they were more confident and acted more efficiently.

Memorability refers to how easy it is to remember how to use the system even after a long period without using it. This attribute was not possible to be tested during the usability testing process, but we hypothesize that the memorability of the application is high. Even though users might forget the meaning of certain illustrations, they now have a description map for this purpose.

The number of **errors** occurring during the system use should be as minimal as possible and easy to recover from. The common error made in the application was related to the order of input selection. By disabling the dropdowns when the previous level was not selected, we were able to prevent this error. Users could also print a version of the School report card without a school selection if they wanted to. This would initiate a modal check.

Satisfaction refers to how pleasant it is to use the system. Even though we could not test the system in the open world, based on the users' feedback from the usability testing, the application offers a pleasant user experience. The improvement provides a better user experience compared to the previous version of the tool.

In conclusion, the usability attributes guided us through the process of usability improvement for the School report card. Even though we could not test the application in typical everyday scenarios, the users' actions and feedback during the usability testing gave us an indication that the applied changes were, in fact, improvements.

8.1.3 Design principles

As presented in chapter three, Jordan P.W. defines ten usability design principles. Out of this list, we extracted and applied five of them during the design process of the prototypes. Since our thesis was part of an ongoing process, we had some limitations going into the project. The process of selecting suited principles for our project was guided by these limitations. Below, we present the selected principles and how they were used in our usability improvement process.

The **consistency** principle suggests that similar tasks are performed in similar ways. In the previous version of the tool, we noticed that this principle was not followed. The school selection area and the resource data were displayed using the same layout. This made it difficult for some users to tell the difference between the two sections and some of them were not able to detect the selection area. After changing the layout of the input boxes and adding a spatial separation, the users were able to provide the input right away.

Designing for **compatibility** means that the manner in which a product works fits in with users' expectations based on their knowledge from experience with similar products. Considering this principle, we decided to place the print button and the language options dropdown on the right-hand side of the application's header and the illustration description map at the bottom of the application. Even though these are the commonly used places for these functionalities, we saw that some users had difficulties finding them. We hypothesize that this was also due to the lack of a mental model for the application and what you can achieve on it.

Another important aspect of the application is the **feedback** provided to the users after their actions. The feedback was presented by displaying a tooltip when the users tried to click on the disabled school dropdown. This approach was very effective for all the users since they were able to explain why the dropdowns were disabled and how to activate them.

Another principle that we took into consideration was **visual clarity**. Since the end-users had vastly different levels of digital proficiency and literacy, it was very important to display the information in such a way that it could be read easily and quickly without causing confusion. The information provided by the tooltip, print modal, and illustrations map was displayed based on the visual clarity principle and, based on the users' feedback, was implemented successfully.

Error prevention and recovery. Errors are likely to occur in every application. Still, we can design and develop in such a way that the possibility of error occurring is minimized, and users can recover quickly from these errors. After testing the first prototype, we saw that the selection dropdowns did not provide any validation for the cases when the previous level was not selected. In order to prevent possible errors, we decided to disable the district and school dropdowns in such cases. Multiple iterations of testing this functionality showed that multiple users tend to use the disabled dropdown, but they quickly realized their mistake by reading the tooltip information. In this way, we managed to prevent the possibility of causing errors in the application.

8.1.4 Usability guidelines for low resource contexts

This section presents the learning outcome of our usability improvement process. After analyzing how the related literature affected our project in the previous section, we will present some recommendations that can be used as a guideline while conducting research or developing for usability in low-resource contexts. These recommendations and the combination of the literature that has affected them are presented in Table 8.1.

While developing for usability, it is crucial to consider all types of potential end-users. Developers can often face the challenging situation of having to design for a wide range of users with a vast difference in literacy and digital proficiency. Since the level of literacy and digital proficiency tends to be quite low in low resource contexts, the developers need to design solutions that can be used by all the intended user groups. In such cases, it is required to make usability attributes trade-offs, such as designing for learnability at the cost of efficiency. In order to make the tool easier to learn, developers might need to limit the number of functionalities and, as a result, this might reduce the tool's efficiency. In addition to these, we highly recommend the use of illustrations for data presentations. By doing this, the information can be conveyed to illiterate people.

While designing and developing for usability, it is essential to consider previous related literature and experiences. Regarding usability, several articles present different sets of usability design principles that can be used as guidance during the research process. However, while developing for low resource contexts, we suggest that based on the nature of the project, one needs to emphasize certain usability principles and potentially filter out some others that can not be applied to the context.

During our usability testing process, we saw that users were not always familiar with design layouts and functionalities we considered as common. The implementation of advanced input elements such as autocomplete did not improve the tool's efficiency, but, on the contrary, it confused the users. We found that design decisions should be influenced by commonly used tools in the context, like WhatsApp and Microsoft Excel in our case.

In developing countries, many tools that existed only in analog format are increasingly being digitalized. In such cases, it is essential to consider the users' existing mental model and prior knowledge. Based on our experience, we would argue that major

Recommendations	Contextual concerns by Li	Usability attributes by Nielsen	Usability design principles by Jordan
Usability attribute trade-offs	X	X	
Use of illustrations for data presentation	X		
Filtration of usability design principles	X		X
Design based on commonly used applications	X		X
Design based on existing mental model and prior knowledge	X		

Table 8.1: Usability guidelines

changes to the new version of the tool can confuse the users, require more training and, as a result, reduce their interest in the tool. Because of this, the designers need to make a trade-off between the use of familiar interfaces and the implementation of new design structures. However, sometimes it will be advantageous in the long run to actually make the leap and design something from the ground up.

8.2 Remote usability testing

One method of evaluating the usability of a system is usability testing. Nielsen describes that usability testing can, to an extent, be used to measure the usability of the design, for example, by analyzing user errors and friction elements found during testing. After analyzing the usability testing research literature, we found that there are multiple different approaches to usability testing. The standard method is considered by many to be laboratory testing within the organization, where the test team invites the participants to a physical location. However, software enables the testing process to be conducted across large distances, and this type of test is now being used at an increasing rate.

As mentioned in chapter 3, remote usability testing is known as the process of testing a system where the test administrator and test participant are separated in space and

potentially also time. A test separated in space is referred to as synchronous testing, while a test that is also separated in time is known as asynchronous testing, and is enabled by testing software. The rest of this sub-chapter will discuss the pros and cons of different usability testing approaches, describe how we designed our test process, and finally present a framework that can be used for projects similar to ours.

Remote vs. Local testing

One of the most fundamental decisions a test team needs to make is whether they want to conduct usability testing locally or remotely. A typical local laboratory test entails inviting the test participants to a test laboratory where they interact with a system through finishing a set of tasks. A traditional setup is illustrated in figure 8.1.

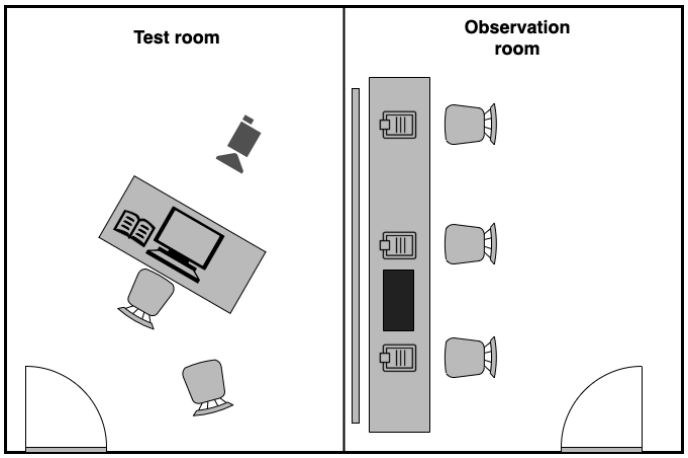


Figure 8.1: Local lab testing

Should the end-users of the system and the test team be separated by large distances, applying, remote usability testing would be an obvious choice. Remote usability testing is enabled by testing software and can either be conducted with a participant setup or with a pre-prepared laboratory located near the end-users. This testing method can also be applied when the spatial separation is not significant, but the convenience and an overall reduction in test time are the primary motivators. If conducted synchronously,

remote usability testing should be a method equally suited to identifying usability issues as local laboratory testing [37].

Sync vs. async

The literature seems to agree that the recommended approach for remote usability testing is synchronous testing. Thompson et al. and Andreasen et al. both found that when conducting asynchronous testing, the average amount of problems identified were lower than with synchronous testing. A reduction in identified problems will reduce the value of the tests as the goal is to identify all potential weaknesses of the system. Likely, this is due to the inability to follow up actions or statements from the participant during testing. However, the benefits of conducting asynchronous testing is the potential reduction in cost and time, and the fact that testing across time zones is easier. With remote synchronous testing, the test team can test the participants' setup before initiating the testing process to ensure the test runs smoothly. This opportunity is lost with asynchronous testing, and test teams risk receiving an incomplete test.

Participant setup vs. pre-prepared laboratory.

A participant setup is where the participants set up their testing laboratory at home as described by a test team. The main benefits of this approach are that the costs of transporting participants to a laboratory are eliminated, and the total amount of time spent is usually reduced. In addition, this approach would enable people from anywhere in the world to contribute to the test process. This approach places much responsibility on the test participants. They have to follow a guide on setting up the laboratory, and it requires them to be quite technically skilled and digitally proficient. Furthermore, remote usability testing with a participant setup requires a preliminary meeting to ensure the quality of the setup [37].

A pre-prepared setup is where the test team has prepared a test laboratory for the participants to interact with the system. By having a pre-prepared laboratory, one will eliminate the need to evaluate the participants' setup, and the test team can be confident that they will get a complete test. One possibility is that one would also get a more accurate representation of end-users, as little responsibility is put on the test participant other than meeting up at a physical location. Having to set up a

test laboratory at home might scare some users away. Of course, this depends on the audience being tested, as a younger user base would likely have less problems with such a setup.

Our approach

The remote nature of our research project and the implications of testing within a low resource context made us adapt and design our own testing process, which we refer to as; **Remote synchronous testing with a pre-prepared laboratory**. Since we were prohibited from visiting the Gambia, it was obvious that we needed to conduct remote usability testing instead of traditional laboratory testing. However, when test teams usually apply remote usability testing, a requirement is that the test participants set up their own laboratory. Due to the contextual circumstances being poor infrastructure, having participants with low digital proficiency and low literacy, we needed to offer an invitation to a pre-prepared laboratory in the Gambia. This was a step made to ensure having a true representation of the potential end-users, not only testing the users that managed to set up a test laboratory. Wi-Fi connection across the Gambia is also poor, so we would still be at the risk of receiving low-quality data if the participants managed to set up a laboratory. The pre-prepared local laboratory in the Gambia was hosted-, and in part managed by MoBSE through tight collaboration and communication with the research team.

In the testing literature, it is common to read about the roles of the test moderator, the observer, and the participant. Even though these roles truly are at the core of any usability testing process, we found that another role was vitally important for the success of our remote testing process within a low resource context, the test supervisor. This role was not mentioned by Thompson et al. or Nielsen, most likely due to the difference in testing setups. Thompson et al. discuss remote usability testing with participant setups, while Nielsen, for the most part, discusses local laboratory usability testing. In both cases, there would be no immediate need to include the test supervisor role described in section 7.2.2.. We argue that our approach required this new role.

The need for a test supervisor becomes apparent when the remote test team evaluates that participant setups are not feasible and that they have to invite the participants

to a pre-prepared laboratory within the participants' local context. In this case, the test team needs someone to manage the participants and can help with any technical difficulties that might occur during testing. A clear advantage of having a pre-prepared laboratory is that the test team only has to train one person on how to set up the test laboratory, removing the need to evaluate the participants' setup before each test.

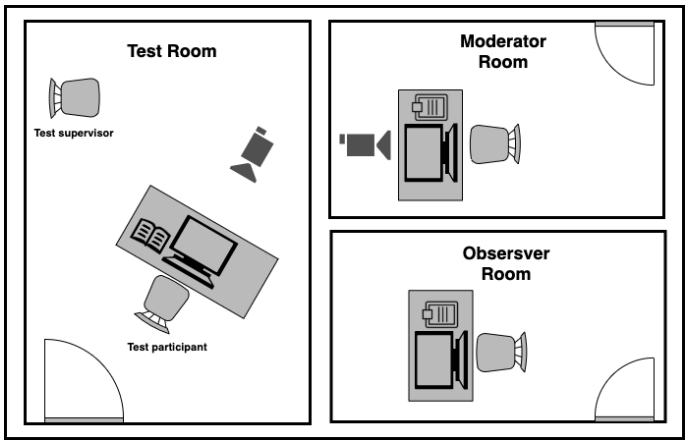


Figure 8.2: Remote usability testing with a pre-prepared lab

The training process of the test supervisor emphasizes the need for a test plan. In addition to budget and a process plan, it also includes a description of the testing motivation, a setup guide, and a detailed role description for the supervisor. One of our findings was that the test supervisor should preferably have little to no experience with the tool, in order to avoid assisting the participant in their tasks during testing. During our process, we clearly asked the participants to avoid assisting the participants in completing their tasks, but since they knew the solution, they felt obliged to help them out of politeness.

A new framework for remote usability testing in low resource contexts Thompson et al. suggested a framework for conducting remote usability testing as an alternative to traditional laboratory testing within the organization as a method to reduce cost and enable a more comprehensive collection of users to test the system. The framework described the main considerations test teams need to make when planning a remote testing process, and it acted as the foundation for the usability testing process of this project. However, vast differences in the context of the article and our project made us

alter the framework to tailor it to our project. Poor infrastructure and significant variance in digital proficiency, education, and literacy within the population guided these new principles for conducting remote usability testing within a low resource context.

Remote usability testing with a pre-prepared laboratory

1. Synchronous testing in a pre-prepared laboratory should mainly be implemented as a usability testing method in situations where the test team is spatially separated both from the target organization and from the end-users of the system, in combination with the test participants having low levels of digital proficiency.

2. Recruiting a test supervisor is pivotal for the success of the testing process and should be trained. The supervisor should be digitally proficient in order to prepare the laboratory and make sure the testing process runs smoothly. It is preferable that this role has little to no experience with the tool to avoid assisting the participant in their tasks during testing.

3. A stable Wi-Fi connection is vital for a nice testing experience by both parties. Repeated connectivity interruptions can agitate participants and testers alike and reduce their patience and motivation. Valuable information can be lost as the participant might refrain from elaborating on their thoughts.

4. Find a testing software that fits the needs of the project. Advancements in technology have enabled test teams to get all-in-one solutions for testing software. Make sure to research alternatives to find the tool that is best suited for the needs of the test process.

5. The responsibility of participant recruitment should be assigned to a person who knows all the potential end-users of the system and is able to find a good representation of these. The recruiting process can have large implications for the test results. It is important that users who truly represent potential end-users are invited to test the system.

6. A detailed test plan should be made by the test team and shared with the test supervisor. Aligning the motivation of the test team and test supervisor can be of great value. The test plan should also include a detailed guide on how to set up the test laboratory and a role description of the test supervisor.

Through our experiences with this project, we recognized that the process of usability testing is not an example of the one-size-fits-all concept. Rather, it is quite the opposite. The testing process needs to be tailored to each specific project. Whether a test team should apply local or remote testing synchronously or asynchronously, have a participant setup, or a pre-prepared laboratory are examples of essential process decisions which will have large implications for the testing output. Project and context limitations guided the test team to design a tailored test process referred to as synchronous remote usability testing with a pre-prepared laboratory. Our experiences resulted in a framework that other teams can follow should they conduct remote usability testing within a low resource context.

Chapter 9

Conclusion

During this project we have worked closely with the Gambian MoBSE to improve their EMIS and community accountability tool; the School report card. This tool was already in use prior to our involvement, but only a handful of people had the opportunity to print out these report cards and share them with their community. We aimed to solve this by first migrating technologies from excel to a third party application within the DHIS2 platform, then performing an iterative process of usability analysis and improvement.

Through this project we used the hybrid research method of action case. This was done by applying a combination of methods from action research and case study. We recognise that in comparison to a full scale action research project our impact on the organisation was of smaller scale, the duration was shorter, and our project involved less people, see table 5.1.

Due to Covid-19 we had to adapt to the restriction of not being able to visit the target context. Knowing that the local environment in the Gambia is vastly different to the one we live in, it would have been of great value to us to conduct research within the field. However, we had to find other ways to collect contextual information. Frequent meetings with actors from the Gambian EMIS along with reading about others experiences became the most influential factors.

9.1 Practical contributions

Going into this project, the main focus was to collaborate with MoBSE to migrate technologies for the School report card. This migration of technologies implied that a lot of users would be able to interact with the digital system instead of exclusively reading and analysing a version of the School report card on paper. The main benefit of this is that more users are able to find the School report card for any school and for any year. Knowing that the application would be used by a greater pool of end-users, we identified the need to analyze the applications usability, and improve it. The end product was a re-designed School report card migrated to the DHIS2 platform designed for users with a variance in digital proficiency and literacy. Our practical contribution can be separated into three parts:

- A usability evaluation of the existing school report card
- A mirror version of the School report card on the DHIS2 platform
- A re-designed version of the School report card on the DHIS2 platform

The usability evaluation of the existing School report card has provided value to policy and practice in utilizing school report cards in the Gambia. The mirror solution enables further work with integrations on the DHIS2 platform. The changes made in the redesigned version of the School report card were based on findings from the usability analysis, and MoBSE now has the opportunity to utilize this tool. Finally, we believe our usability findings of this project can be of relevance to other countries and ministries who are using, or are planning to implement, similar community tools.

9.2 Theoretical contributions

Usability in low resource contexts

The focus of this thesis has been designing and developing for usability in low resource contexts. Even though there are many articles related to the topic of usability, we found that their focus on the implications for designing and developing for low resource contexts is limited. We made an effort of combining a set of literature to better understand what affects this process, and as a result we came up with a list of recommendations designers and developers can consider while developing systems for low resource contexts with an emphasis on usability.

Developing for a wide range of users with a vast difference in literacy and digital proficiency can be quite challenging. In order to make applications usable for all user groups, developers should consider making usability attribute trade-offs. Using illustrations for data presentation and designing based on the users' commonly used applications will result in higher involvement of the lower literacy and low digital proficiency user groups. Even though the usability design principles can provide great help during the design process, some of these principles can not be applied to all contexts. Therefore, one should consider filtering the usability design principles. In cases when there is an existing version of the tool, we recommend to heavily consider the user's existing mental model and prior experience.

Remote testing framework

Due to Covid-19 we found ourselves in need of a remote testing process that was suited to a context with poor internet infrastructure, that would put a low amount of responsibility on the test participants' digital skills and required tools. As we could not find a framework that suited our specific needs, through this project we built on others' experience within the usability testing literature and customized one of our own.

We now offer a framework to guide test teams in planning for remote testing within low resource contexts. When referring to "remote usability testing" the literature is often referring to remote synchronous or asynchronous testing with a participant setup, we would like to challenge this unwritten rule. We argue that for remote usability testing in low resource contexts the test team should invite participants to a pre-prepared laboratory within their local community, while the test moderator and observer joins the test remotely. Should test teams select this approach, they could in theory avoid

visiting the context altogether. The setup is dependent on the hiring of a test supervisor, a test managing role that should be technically proficient, while preferably having no previous experience with the system being tested. It is important to stress that remote usability testing with a pre-prepared laboratory requires close collaboration with the organisation, but can yield effective results if executed correctly. After all, Thompson et al., Andreasen et al., and Huang et al. all state that as long as remote testing is conducted synchronously, one should be able to identify just as many usability issues as with the traditional local laboratory setup. In the end, it is down to the experience and performance of the test team that is the deciding factor on the quality of the usability findings [21].

9.3 Future work

Our interpretation of the usability literature as a whole is that there is a decent amount of literature written about designing and testing for usability in low resource contexts, but they often refrain from describing the implications of how the context affects these projects. Therefore, we encourage more research to write about the direct implications of designing and developing for usability in low resource contexts as this can be great insight for projects to come.

Design principles were included to guide a usable design, and we found that not all of the principles were applicable to our context. There is no way we could validate that our filtration was correct. A framework to guide designers and developers in how to select guiding principles for projects in low resource context would have been useful.

We encourage other researchers to apply this new remote testing method to see if more projects can benefit from our findings. Since the research team of this project has very limited experience we are sure there are a lot of potential improvements to be made.

Furthermore, we believe that our usability design recommendations were influenced by our specific context and we believe other researchers should evaluate whether or not these recommendations hold for similar contexts.

Bibliography

[1] Shrøder S O Stage J Andreasen M S, Nielsen H V. What Happened to Remote Usability Testing? An Empirical Study of Three Methods[internet]. CHI 2007. Available from: https://doi.org/10.1145/1240624.1240838, 2007, April. Accessed: 10.04.2021. Pages 1405-1414.

[2] Shackl B. Usability – Context, framework, definition, design and evaluation[internet]. Interacting with Computers. Available from: ttps://doi.org/10.1016/j.intcom.2009.04.007, 2009, December. Accessed: 10.04.2021. Pages 339–346.

[3] Bansang educational appeal. Education in The Gambia[internet]. Available from: https://www.bansangeducationalappeal.org/education-in-the-gambia.html. Accessed: 09.02.2021.

[4] Maissel J Bevan N, Kirakowski J. What is Usability?[internet]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.630.1555&rep=rep1&type=pdf, 1991, September. Accessed: 10.04.2021.

[5] Vigden R T Braa K. Interpretation, intervention, and reduction in the organizational laboratory: a framework for in-context information system research[internet]. Information and Organization. Available from: https://www.uio.no/studier/emner/matnat/ifi/INF5571/v15/timeplan/ar-docs/braa-vidgen-1999-interpretation-intervention-and-reduction.pdf, 1999. Accessed: 22.03.2021.

[6] CIA. Gambia,the [internet]. Available from: https:

//www.cia.gov/library/publications/the-world-factbook/geos/rw.html. Accessed: 24.11.2020.

[7] CIA. GA summary[internet]. Available from: https://www.cia.gov/the-world-factbook/static/e5fff4dbbfe6b66ec821780e1f920a15/GA-summary.pdf. Accessed: 01.02.2021.

[8] Braun V Clarke V. Thematic Analysis, Chapter 4. Available from: https://www.academia.edu/3789893/Thematic_Analysis, 2012. Accessed: 03.03.2021.

[9] DHIS2. About DHIS2[internet]. Available from: https://dhis2.org/education/. Accessed: 24.11.2020.

[10] DHIS2. DHIS2 for Education[internet]. Available from: https://dhis2.org/education/. Accessed: 04.04.2021.

[11] DHIS2. DHIS2 Software Overview. Available from: https://dhis2.org/overview/. Accessed: 24.11.2020.

[12] Edugambia. Education response strategy to COVID-19[internet]. Available from: http://www.edugambia.gm/. Accessed: 10.01.2021.

[13] Jacko J A Sainfort F Edwards P J, Moloney K P. Evaluating usability of a commercial electronic health record: A case study[internet]. International Journal of Human-Computer Studies. Available from: https://doi.org/10.1016/j.ijhcs.2008.06.002, 2008. Pages 718-728. Accessed: 07.04.2021.

[14] ESLint. Getting Started with ESLint[internet]. Available from: https://eslint.org/docs/user-guide/getting-started. Accessed: 06.01.2021.

[15] Git. git [internet]. Available from: https://git-scm.com/. Accessed: 08.12.2020.

[16] Gomez S, Bah A. How EMIS data drive education reforms: The case of The Gambia[internet]. Available from: https://www.globalpartnership.org/blog/

how-emis-data-drive-education-reforms-case-gambia. Accessed: 12.02.2021.

[17] Hua H Herstein J. Education Management Information System (EMIS): Integrated Data and Information Systems and Their Implications In Educational Management[internet]. Available from: http://dqaf.uis.unesco.org/images/1/1c/Herstein-hua_2003.pdf, 2003, March. Accessed: 12.02.2021.

[18] Payne T L Rogers J B Huang S, Bias R G. Remote Usability Testing: A Practice[internet]. JCDL '09: Proceedings of the 9th ACM/IEEE-CS joint conference on Digital libraries . Available from: https://doi.org/10.1145/1555400.1555481, 2009, June. Pages 397–398. Accessed: 10.04.2021.

[19] Lennung S. Hult M. TOWARDS A DEFINITION OF ACTION RESEARCH: A NOTE AND BIBLIOGRAPHY[internet] . Available from: https://onlinelibrary-wiley-com.ezproxy.uio.no/doi/epdf/10.1111/j.1467-6486.1980.tb00087.x, 1996. Accessed: 22.03.2021.

[20] Benbasat I. The Case Research Strategy in Studies of Information Systems. Available from: https://www.jstor.org/stable/248684?seq=1#metadata_info_tab_contents, 2000. Accessed: 22.03.2021.

[21] Nielsen J. Usability engineering. USA: Academic Press; 1993, 1993.

[22] Lewis J.R. Usability Testing. Available from: http://sistemas-humano-computacionais.wdfiles.com/local--files/capitulo%3Amodelagem-e-simulacao-de-sistemas-humano-computacio/usabilitytesting-ral.pdf. Accessed: 10.04.2021.

[23] Li M. Utilizing the space for user participation: experiences from a public health project in Uganda. In: Information Systems Research Seminar in Scandinavia[internet]. https://www.duo.uio.no/bitstream/handle/10852/62760/1/Master-Magnus-Li.pdf, 2017. Accessed: 07.04.2021.

[24] Li M. Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D: Usability Problems and Obstacles to Addressing Them in Health Information Software Implementations. https://link-springer-com.ezproxy.uio.no/chapter/10.1007/978-3-030-19115-3_20, 2019. Pages 241-252. Accessed: 07.04.2021.

[25] Ministries of Basic and Secondary Education and Higher Education Research Science and Technology. Education Sector Strategic Plan 2016 – 2030. Available from: https://www.globalpartnership.org/sites/default/files/2018-09-the-gambia-essp-2016-30.pdf. Accessed: 02.04.2021.

[26] MoBSE. The Gambia Education Report Cards Preparation procedures and assumptions note. Private.

[27] Nielsen. Why You Only Need toTest with 5 Users. Available from: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/. Accessed: 30.03.2021.

[28] Stack overflow. Developer Survey Results 2019[internet]. Available from: https://insights.stackoverflow.com/survey/2019#technology. Accessed: 06.01.2021.

[29] Showkat N. Parveen H. Data collection[internet]. Available from: https://www.researchgate.net/publication/319128325_Data_Collection. Accessed: 21.02.2021.

[30] Venugopal V Post D, Agarwal S. Rapid Feedback: The Role of Community Scorecards in Improving Service Delivery. Available from: http://documents1.worldbank.org/curated/en/462221468333561977/pdf/884970WP0Rapid00Box385225B00PUBLIC0.pdf. Accessed: 20.04.2021.

[31] Single H.M. Powell R.A. 'Focus groups', International Journal of Quality in Health Care. Available from: https://www.researchgate.net/publication/233894975_Focus_Groups, 1996. Accessed: 21.02.2021.

[32] Prettier. What is Prettier?[internet]. Available from: https://prettier.io/docs/en/index.html. Accessed: 06.01.2021.

[33] Jordan P.w. An introduction to usability. CRC Press; 1998.

[34] Baskerville R. INVESTIGATING INFORMATION SYSTEMS WITH ACTION RESEARCH[internet]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.982.6795&rep=rep1&type=pdf, 2000. Accessed: 22.03.2021.

[35] React. react [internet]. Available from: https://reactjs.org/. Accessed: 08.12.2020.

[36] Global Education Monitoring Report Team. Education for All by 2015: will we make it? EFA global monitoring report, 2008[internet]. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000154743. Accessed: 12.02.2021.

[37] Haake H.R. Thompson K.E., Rozanski E.P. Here, There, Anywhere: Remote Usability Testing That Works. Available from: https://dl-acm-org.ezproxy.uio.no/doi/pdf/10.1145/1029533.1029567. Accessed: 10.04.2021.

[38] Trello. Trello helps teams move work forward[internet]. Availble from: https://trello.com/en. Accessed: 08.12.2020.

[39] UNESCO. Education and literacy[internet]. Available from: http://uis.unesco.org/en/country/gm. Accessed: 11.02.2021.

[40] UNICEF. Education[internet]. Available from: https://www.unicef.org/gambia/education. Accessed: 30.03.2021.

[41] University of Oslo. Health Information Systems Programme (HISP)[internet]. Available from: https://www.mn.uio.no/ifi/english/research/networks/hisp/. Accessed: 12.12.2020.

[42] W3.org. Usability - ISO 9241 definition[internet]. Available from: https://www.w3.org/2002/Talks/0104-usabilityprocess/slide3-0.html. Accessed: 10.04.2021.

[43] World Bank. Population, total - Gambia, The[internet]. Available from: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=GM. Accessed: 28.03.2021.

[44] World Bank. The Gambia: Education Sector Public Expenditure Review[internet]. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/28942/Output-Gambia-PER-Oct-2017.pdf?sequence=1&isAllowed=y. Accessed: 28.03.2021.

[45] Dittrich Y. Software engineering beyond the project–sustaining software ecosystems. Inf. Softw. Technol., 2014. Pages 1436-1456.