Culturally-relevant Augmented User Interfaces for Illiterate and Semi-literate Users

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Abstract - This thesis discusses guidelines for developers of Augmented User Interfaces that can be used by illiterate and semi-literate users. To discover how illiterate and semi-literate users intuitively understand interaction with a computer, a series of Wizard of Oz experiments were conducted. In the first Wizard of Oz study, users were presented with a standard desktop computer, fitted with a number of input devices to determine how they assume interaction should occur. This study found that the users preferred the use of speech and gestures which mirrored findings from other researchers. The study also found that users struggled to understand the tab metaphor which is used frequently in applications. From these findings, a localised culturally-relevant tab interface was developed to determine the feasibility of localised Graphical User Interface components. A second study was undertaken to compare the localised tab interface with the traditional tabbed interface. This study collected both quantitative and qualitative data from the participants. It found that users could interact with a localised tabbed interface faster and more accurately than with the traditional counterparts. More importantly, users stated that they intuitively understood the localised interface component, whereas they did not understand the traditional tab metaphor. These user studies have shown that the use of self-explanatory animations, video feedback, localised tabbed interface metaphors and voice output have a positive impact on enabling illiterate and semi-literate users to access information.

Contents

List of Figures

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List of Publications

The research derived from this thesis resulted in the following publications:

1. T. Gavaza, H. Thinyane, and A. Terzoli. Augmented user interfaces for access for illiterate and semi-literate users. In *Proceedings of SATNAC 2009,* Swaziland. EE Publishers, 2009.

2. H. Thinyane, T. Gavaza, and A. Terzoli. An investigation into culturally-relevant GUI components within marginalised South African communities. In *Proceedings of the 5th IDIA Conference: IDIA2011 Conference.* Peru, 2011.

Chapters 5 and 6 were the basis of the two published conference papers.

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Chapter 1

Introduction

The use of text-based user interfaces (UI) requires users to be literate. According to a 2001 estimation by the Summer Institute of Linguistics (SIL) International [49], approximately 95% of illiterate people are living in the developing world. With these high rates of illiteracy, potential users are being excluded from services and necessary information that can be vital to health and employment in developing countries. Although many researchers and other international agencies are taking steps towards bridging the digital divide by trying to improve web access in developing countries, combating information poverty requires more than providing web terminals. It also requires designing methods and tools for people with weak reading skills to navigate, explore and use the web to find and understand the information presented there. Deployment of interfaces from developed countries to developing countries has been most unsuccessful because of a mismatch between the intended environment for which the technology was primarily designed, and the realities of the environments in which they are deployed [143]. Many Information and Communication Technology (ICT) initiatives involve the use of standard web-based forms or Window-based Graphical User Interfaces (GUIs) as the primary interface and the Internet for connectivity. According to Tedre, Sutinen, Kahkonen and Kommers [143], most current GUIs were designed with a specific user in mind, one who is literate and who uses a language that has a written form. These GUIs were primarily designed for western countries and office automation. The use of these GUIs in the developing world is problematic because of high illiteracy rates.

1.1 Problem Statement

This study investigates the development of Augmented User Interfaces (AUI) that are more intuitive to illiterate and semi-literate users. The main objective is to develop a set of guidelines that can be used by developers to design AUIs such that illiterate and semi-literate users can intuitively interact with a computer.

1.2 Research Goals

For a successful investigation of AUIs for illiterate and semi-literate users, the following research goals were set:

1. Determine state of the art in UIs for illiterate and semi-literate users.
2. Perform a Wizard of Oz (WOz) study to determine intuitive methods of interaction and identify current problems faced by illiterate and semi-literate users.
3. Once problems have been identified, design and evaluate localised solutions.
4. Design guidelines for creating AUIs.

1.3 Scope Of Research

The research carried out as part of this thesis showed the difficulties in designing AUIs and making them accessible to illiterate and semi-literate users. This thesis initially investigated guidelines for creating AUIs. Findings from this initial investigation (discussed in Section 5.3) tallied with findings from other research, excluding problems faced when users interacted with tabbed user interfaces. The research focus, therefore changed to localised tabbed UI metaphors.

In this thesis, illiterate users refers to users who are unable to read and write and have never used a computer before. Semi-literate users in this context refers to users who are able to read and write to an elementary level but have never used a computer before (computer illiterate). Literate users in this context refers to users who are able to read and write and are also computer literate.

In this thesis, the Dwesa community and peri-urban areas around Grahamstown were used to test the UIs developed during this study. These areas were chosen due to the low literacy levels and the fact that large portions of people in these areas have no experience with a computer. They also represent different types of previously marginalised communities where 42.5% of South African population live [2, 139]. A more detailed description of these communities is given in Chapter Two. Findings are therefore localised to these rural and peri-urban areas of the Republic of South Africa.

1.4 Summary Of Findings

The results of the studies carried out show that presenting the required task on the same page without the need to scroll down makes it more intuitive to illiterate users. The use of self-explanatory images without any text enables interaction and well known symbols are easily recognised by both semi-literate and illiterate users.

The use of video and speech feedback is also helpful to both illiterate and semi-literate users.

Findings also show that both illiterate and semi-literate users interact faster with a localised tab metaphor interface (LTMI) compared to a traditional tab metaphor interface (TTMI). They also commit less errors on the LTMI compared to the TTMI.

All semi-literate users managed to complete their tasks on both interfaces while some illiterate users failed to complete their given tasks.

The LTMI had a large success rate because users were able to preview the page to which they were moving and could get a description of the page.

1.5 Structure Of This Document

This thesis is structured into eight chapters.

Chapter Two discusses a background study on the target group. Two sites were chosen to represent rural and peri-urban areas where the literacy levels are low. The chapter discusses the digital divide and the challenges faced by communities in developing countries.

Chapter Three presents the work relevant to this study. It discusses previous and on-going research on UI design, specifically on illiterate and semi-literate users. The Chapter also goes on to discuss ethnocomputing and introduces the WOz technique.

Chapter Four discusses the spiral-model methodology that was followed.

Chapter Five discusses the WOz study that was carried out to understand how illiterate and semi-literate users intuitively interact with computers. Results of this study are also presented.

Chapter Six discusses a localised user study that followed after the WOz study. A LTMI was created and tested against the TTMI. The results of the localised user study are presented in this chapter.

Chapter Seven presents guidelines for creating Augmented User Interfaces for illiterate and semi-literate users.

Chapter Eight concludes this document and recommends work to be carried out in the future.

Chapter 2

Background: Users And The Environment Of Study

It is important to understand the current economic and social status of a community when introducing ICTs. This knowledge facilitates the introduction of relevant ICTs that are useful to the community. This chapter discusses the environment in which user studies were performed. Participants in this research were either from the peri-urban areas around Grahamstown or from the rural areas of Dwesa. These two sites are representative of the underdeveloped areas of South Africa. This chapter discusses the users, their capabilities, their literacy levels and environment in which they live. The discussion regarding the Dwesa community is based on the report of a baseline study carried out by Pade-Khene, Palmer and Kavhai [117] in 2010, while the discussion regarding peri-urban areas around Grahamstown is based on a sample survey of 1 020 households conducted on 23 residential neighbourhoods by Moller, Manona, Hees, Pillay and Tobi [101] in November 2007.

2.1 Dwesa Community Life

The Dwesa community is one of the least-developed areas of the former Transkei in the Eastern Cape Province of South Africa. According to Palmer, Timmermans and Fay [119], the area was previously declared a labour reserve and was systematically underdeveloped so that laborers could be encouraged to move to farms, mines and cities. The area currently houses approximately 15 000 people who live between the Dwesa-Cwebe Nature and Marine Reserve, an area covering about 6 000 hectares [117]. The location of the

Dwesa community is shown in Figure 2.1. The poverty in this area is directly associated with the history of the area.

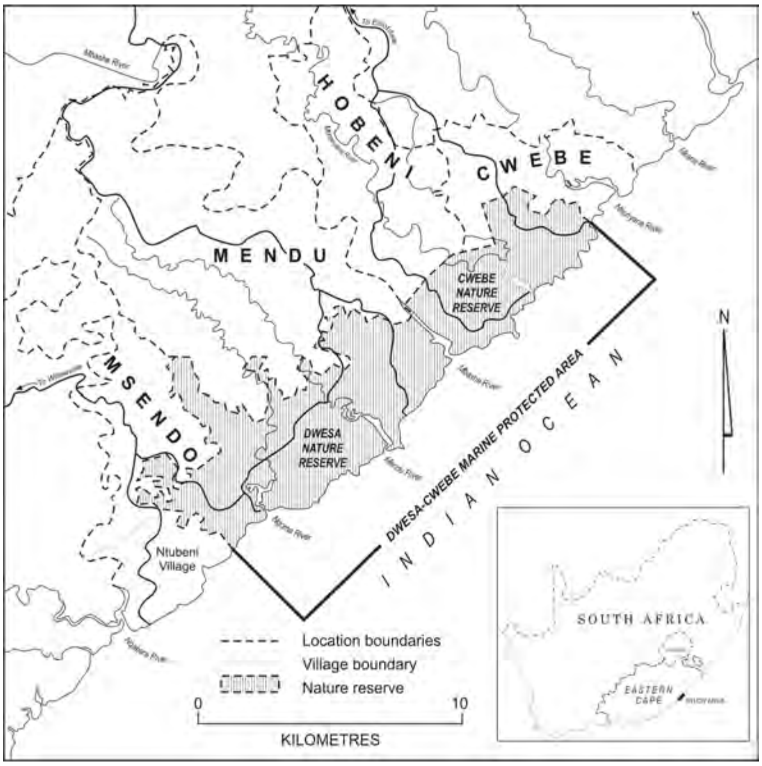

Figure 2.1: Location of the Dwesa Community[117]

Pade-Khene *et al.* [117] group people from this community into five categories: teachers, crafters, the unemployed, the youth and the elderly. Each of the above-mentioned groups had their own views about the Dwesa community.

Teachers were one group that had more experience with the outer world than most people in the community. They pointed out the need for infrastructure and services locally. They were also concerned about the rise in crime and drunkenness due to unemployment. Drinking, dropping out of school and teenage pregnancy were some of the factors that have been affecting the literacy level of the community[117].

Crafters shared their views with the teachers. They were happy with their way of life although it was a great challenge and even close to impossible to make a living out of crafting alone. As a result, they also practiced agriculture to support themselves and their families. Most of them joined the Siyazindla agricultural project and other on-going poverty relief projects. The nature reserve provides them with all the raw materials they need for creating their products. Figure 2.2 shows the local crafters at work. Other challenges faced by crafters include the absence of support and a market while an e-commerce system [130] was developed for selling their crafts and agricultural products but most of the crafters lack expertise in using it.

Figure 2.2: Local crafters at work [117]

Unemployed people in the community blamed bad roads and lack of electricity for their unemployment. Most of them had no plans for getting themselves out of their situation; they looked forward to the coming of businesses into their community including lodges and hotels that had been promised to them.

Youth are reluctant to move out of the Dwesa community until they have completed their studies or have employment ready for them [117]. They were also comfortable with their current lifestyle arguing that life was cheap since they could survive without any money and make a living from agriculture and the natural resources available.

Most of their comfort was a result of the fact that their parents were providing for them. They also enjoyed some entertainment activities like playing soccer, listening to music and walking on the beach.

Elderly people had been out of the community before. They mentioned the unavailability of farming equipment such as tractors and the need to find solutions to pigs that were destroying their crops [117].

2.2 Grahamstown Community Life

Grahamstown is a small city located in the Eastern Cape province of South Africa. Figure 2.3 shows a map of Grahamstown. The Eastern Cape is one of South Africa's poorest provinces with a high unemployment rate. According to Dowse and Ehlers [34], 20% of adults living in and near Grahamstown have no formal education.

Figure 2.3: Location of the Grahamstown Community [101]

Unlike the Dwesa community that was initially a reserve for farm and mine laborers, Grahamstown was initially a military garrison that attracted Xhosa and Khoi people who settled there [100]. The black population in Grahamstown was never resettled.

Over 50% of the households in Grahamstown live in houses made of brick or cement blocks. Three quarters (76%) of homes in peri-urban areas around Grahamstown have a constant supply of electricity. By 2001, 72% of households owned a television and 84% owned a radio. Cellphone ownership rose to 32% by 2001. There is also a constant supply of newspapers, although most people are reluctant to buy them because they cannot read or afford to buy one every day. Although many have previous experience with ICTs such as radios, newspapers, televisions and cellphones, people in areas around Grahamstown do not have enough skills to interact with computers.

Unlike in the Dwesa community where most of the employed people are teachers, Grahamstown has more employment opportunities. Crafting is less common in Grahamstown compared to the Dwesa community. Over half (51%) of the households in Grahamstown have a vegetable garden and 69% of the remaining households would like to own one.

The population in peri-urban areas around Grahamstown can be classified into four categories: the Unemployed, the Employed, the Youth and the Elderly. No interviews were performed to find out their views about Grahamstown. The unemployed constitute 18% of the population while the employed (formal, informal and casual work) constitute 16%. The youth and elderly constitute the remaining 66%.

The previous section discussed the current situation in both Dwesa community and peri-urban areas around Grahamstown. The following section briefly discusses the digital divide and how it is affecting rural areas of developing countries.

2.3 Digital Divide And Technological Literacy Of Users

Modern technology and reliable electricity supply are among some of the common amenities that are scarce in most rural areas of developing countries [151]. The above two factors widen the accessibility gap of information and ICTs among urban areas and rural communities in developing countries. The accessibility gap is normally referred to as the "digital divide" and impacts this study's target group. Within this investigation two sites were used to represent rural and peri-urban areas of South Africa: the Dwesa community and informal settlements surrounding Grahamstown. The following subsection discusses the definition of the term "digital divide" and how it affects the Dwesa community and peri-urban areas around Grahamstown.

2.3.1 Digital Divide

The term "digital divide" refers to the gap between people with access to digital and information technology and those with no access at all. According to Hargittai [61], more than 90% of the world's population has never used the Internet.

Yonah [155], identifies three critical success factors to bridging the digital divide:

1. *connectivity* - are services available?
2. *affordability* - can the user afford the services?
3. *capability* - do the users have the technical abilities, language and literacy to use the ICTs?

Using Yonah's factors, even if the services are available (connectivity) at a price that is affordable to the users (affordability), if the users do not have the capability to use the ICT, the technology will be to no advantage. Figure 2.4 explains some of the factors that are widening the digital divide in peri-urban and rural communities of developing countries, including the Dwesa community and settlements around Grahamstown. Low-income jobs and unemployment make it difficult to afford computer hardware, electricity and Internet access, thus reducing connectivity. The resulting lack of information and computer technology skills affects the capabilities of the user. Islam and Alawadhi [70] suggest that ownership of ICTs is the first step to bridging the digital divide followed by connectivity and then the ability to use the ICTs.

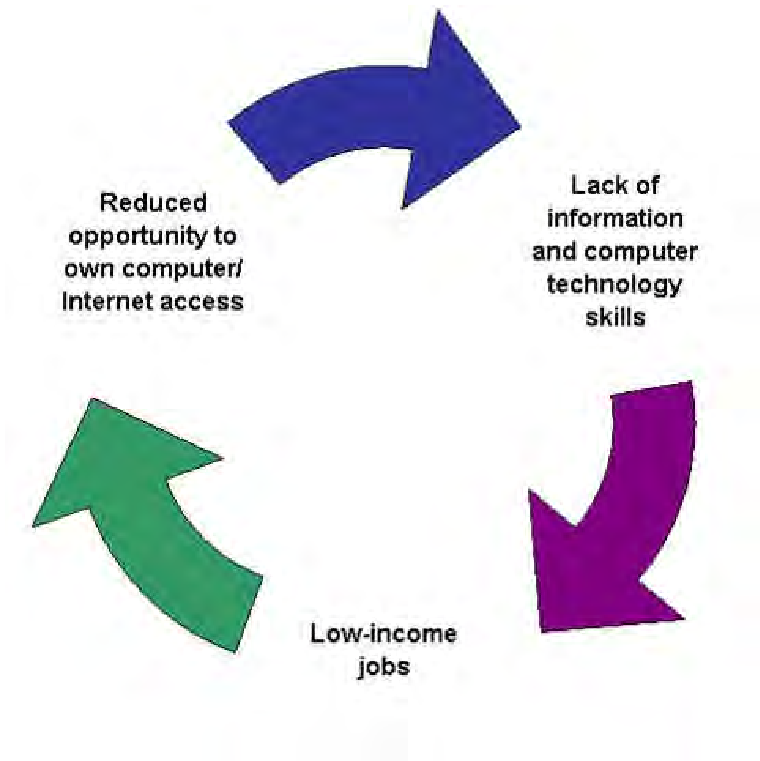

Figure 2.4: Factors affecting the digital divide [39]

2.3.2 Challenges to Technology Use

As mentioned in the previous subsection, some of the challenges faced in developing countries include affordability, connectivity and capability. This section describes the above-mentioned factors and how they affect the communities in this study.

Affordability - large portions of the population in rural and peri-urban areas are unemployed. According to a baseline study by Pade-Khene *et al.* [117] carried out in 2009, most people in the Dwesa community were living on an income of less than R375 a month per adult. In this case, affordability denies people the ability to own any ICT infrastructure. Pade *et al.* [117] have shown that 88% of the Dwesa population is unemployed and only 42% are looking for employment; the other 46% have given up hope of finding employment. Figure 2.5 shows the employment status of people in the Dwesa. The graph shows that more than 30% of the community are unemployed. Close to 40% of the people who are not studying are employed part-time or self-employed. According to the survey carried out by Moller *et al.* [101] in 2007, 18% of the Grahamstown population were employed either full-time or part-time, while 6% claimed that they were self-employed. Thirty eight percent of the households reported that a household member was employed full-time and 35% reported that a household member was employed part-time or had a casual job. Most of the employed people earned an average of R1 100 per month per household by 2007, while the study carried out by Moller *et al.* [101] stated that households needed R2 900 or more to live a comfortable life. With these low employment rates and low incomes among the working classes in rural areas of the South Africa, affordability of ICTs becomes a challenge.

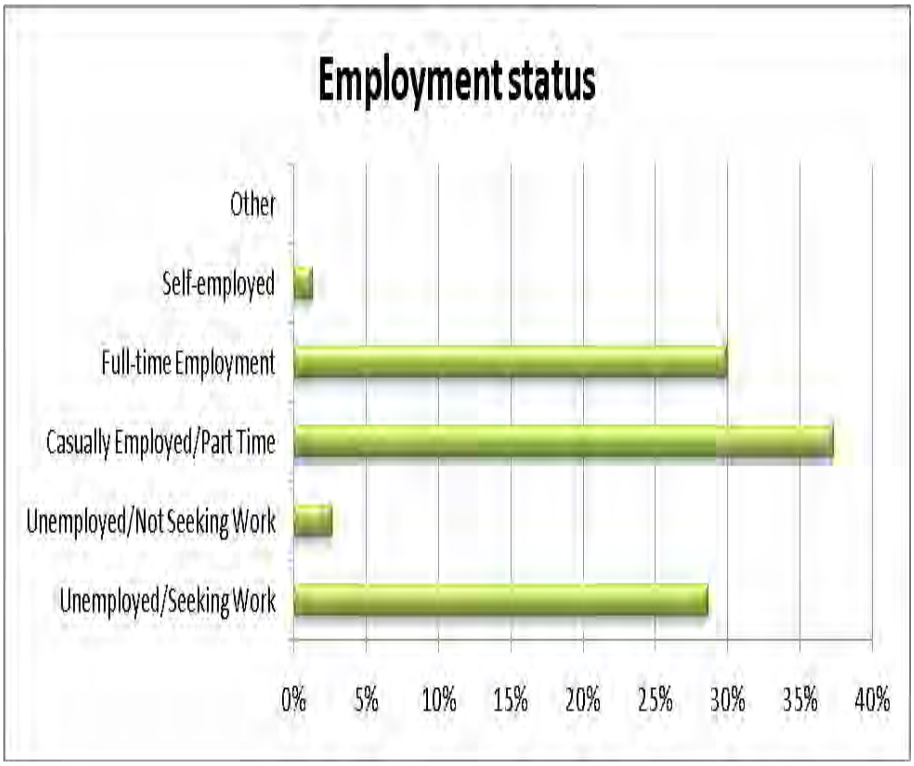

Figure 2.5: Dwesa employment status (excluding students who are currently studying)[117]

Connectivity is one of the challenges faced by most rural and peri-urban areas in South Africa and most developing countries. According to a baseline study by Pade-Khene *et al.* [117] carried out in 2009, close to 94% of households in the Dwesa community did not have any form of electricity. As shown in figure 2.6 only 1% of the population use Eskom electricity and generator power while 4% use solar power. This makes the connectivity of any ICTs difficult.

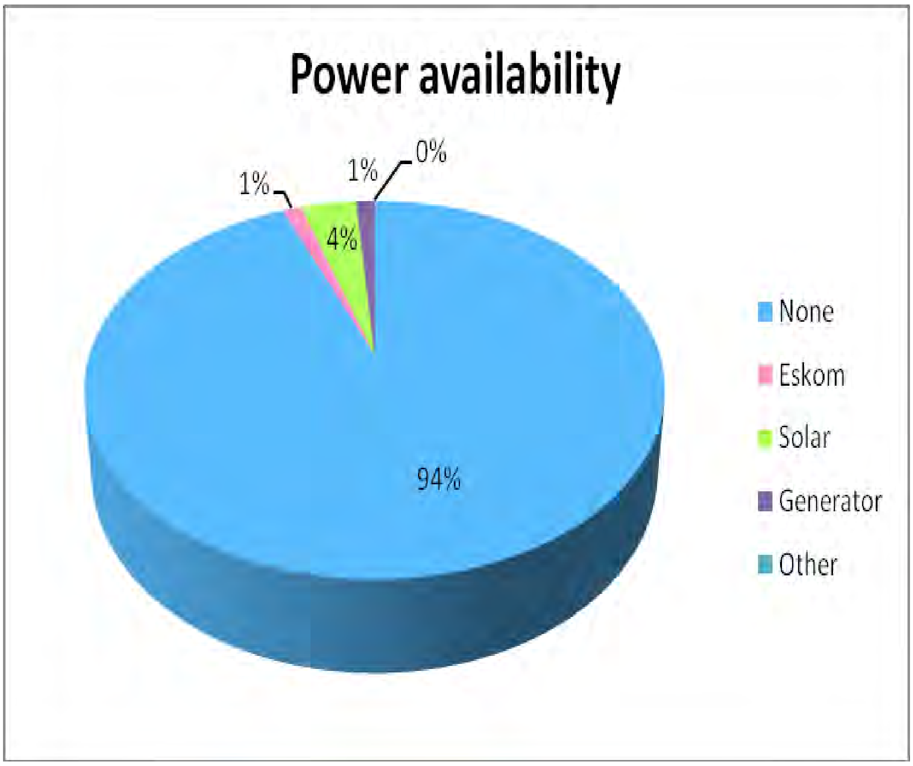

Figure 2.6: Electricity Distribution in Dwesa[117]

Contrary to the situation in the Dwesa community, 76% of the households in peri-urban areas around Grahamstown have a constant supply of electricity. Despite these challenges, the Siyakhula Living Lab (SLL), a joint venture between the Telkom Centres of Excellence of the University of Fort Hare and Rhodes University, with the support of the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA), provides all the infrastructure needed to provide ICTs for the Dwesa community.

Capability - the SLL aims to equip semi-marginalised and marginalised communities with ICT skills. The SLL has trained people on the use of computers based on Open Office Edubuntu software. They also provide training on the use of the Internet. Some trainees use the Internet to look for information while others use the Internet to download important forms like revenue forms.

Despite the presence of the SLL, most Dwesa people are not familiar with the use of computers [117]. Teachers constitute 75% of the trainees and most people from the community are not aware of the program. About 89% of the community do not have the knowledge and basic skills of using a computer [117].

Thus while the introduction of the SLL helped to solve the problems of connectivity and affordability of ICTs in the Dwesa community user capability remains a challenge. Large portions of the Dwesa population and peri-urban areas around Grahamstown are either illiterate or semi-literate. While standard personal computers, UIs and Internet access were provided by the SLL, illiterate users were not able to use the keyboard to type any input or read the text displayed on the UI. Even semi-literate users found it difficult to browse and search for information as the interface had not been localised. Refer to Section 3.3.5.2 for more on localisation of interfaces. Although Grahamstown is a city with long-established independent schools, the literacy levels among the surrounding communities remain low. According to Hendricks [62], poorly-resourced state schools are one of the factors leading to low literacy levels in rural areas and townships. According to the study carried out by Moller *et al.* [101], 14% of the people around Grahamstown have no education while 36% have attended school up to grade five. Dowse and Ehlers[34] argues that at least 20% of adults around Grahamstown have no formal education.

The following subsection discusses common ICTs among the Dwesa community and peri-urban communities around Grahamstown. It also discusses how familiar they are with these ICTs.

2.3.2.1 Previous Technology and Communication Experience

Despite the challenges faced by the Dwesa community and peri-urban areas around Grahamstown, the results from a baseline study carried out by Pade-Khene *et al.* [117] and the survey carried out by Moller *et al.* [101] show that these communities have some previous experience with ICTs. These ICTs can be categorised into Traditional ICTs (radios, television and newspapers) and Modern ICTs (cellphones) [117].

Traditional ICTs such as radios are common in most houses in the Dwesa community. About 57% of households own a radio or have access to a radio [117]. This allows them to listen to music and news. Most people only have the opportunity to watch a television when they visit the local shop since only 6.25% of the population own a television. The main reasons for not owning one are affordability and lack of electricity. Newspapers are rare in Dwesa because of the problem of delivery due to bad roads; even when they are available, people are reluctant to buy them. Newspapers can, however, be found at the nearest town, Willowvale.

In recent years, cellphones have been the most prevalent modern ICT in rural areas, including the Dwesa community. Although cellphones are the most widely used ICT in rural areas, not all people own or have access to one. Studies carried out by Pade-Khene *et al.* [117] have shown that the use of cellphones has increased over the past two years. Figure 2.7 shows how long people have owned a cellphone. Close to 70% of the cellphone owners have used them for two years or less. Most of the cellphones are used to communicate with people who are outside the Dwesa community as they prefer using face-to-face communication around the community. Although 3G phones are available, they are not used to their full capabilities. Phones are only used for calling and text messaging as villagers are not aware of all the capabilities of their 3G phones such as accessing government information, the Internet and banking services.

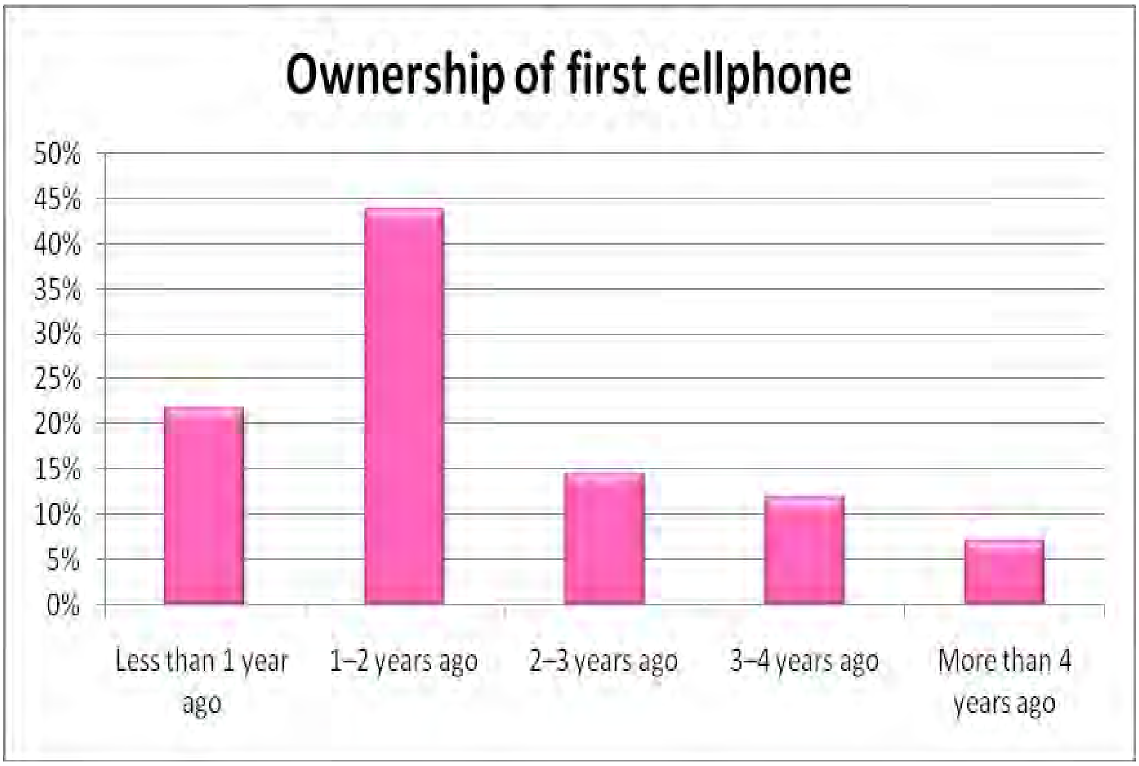

Figure 2.7: Number of years people have owned a cellphone [117]

This section has shown that the target group has some previous experience with traditional ICTs and that cellphones are the most popular modern ICT with which they are familiar.

2.4 Summary

This chapter discussed the Dwesa community and peri-urban areas around Grahamstown and their current lifestyle. It also discussed the problems they face with modern ICTs.

All these communities have had some previous experience with ICTs although most of their previous ICTs did not require any literacy. The introduction of computers has posed several challenges due to the interfaces provided. The current UIs require a certain level of literacy to interact with them without assistance. The following chapter discusses previous attempts to help illiterate and semi-literate users access information on computers.

Chapter 3

Related Work

This chapter discusses previous attempts to help people with limited capabilities to access information on desktop computers. It discusses general design principles; design for illiterate and semi-literate users; and, the incorporation of culture into design for illiterate and semi-literate users.

3.1 User Interface Design

User interface (UI) design is an important factor for the usability of any system [114]. The first step in designing for different users is to understand the values of the target audiences. Cultural, life and world events which connect with the users' youth and upbringing will affect how users view the UI. Designers must understand what is important to the users and the environment in which the system will be used.

Requirements referring to specific features and standard UI design are discussed in this section. Information presentation methods appropriate for UI design are also proposed. Standards have been developed for defining the usability of software products. These standards are based on observed and theoretical studies of human factors done in the seventies and eighties. The International Federation for Information Processing (IFIP) UI reference model proposes the following four measurements to structure the UI, according to Dzida [37] :

1. the output/input interface which deals with the look of the UI,

2. the dialogue interface which deals with the feel of the UI,
3. the functional interface which deals with access to tools and services,
4. and the organisational interface which deals with co-operation and communication support.

The IFIP model describes the requirements for interface usability [147]. It has influenced many international standards including the ISO 9241 [125]. Usability is defined by the effectiveness, efficiency and satisfaction of the user where effectiveness refers to the extent to which the user's goals are achieved; efficiency refers to the resources that are used to achieve the goals; and, satisfaction refers to the degree to which the user finds the system acceptable.

Dialogue requirements of a system are set out in the following seven principles as taken from Oppermann [114]:

1. *task suitability*: measured by how efficient and effective a dialogue supports task-completion.
2. *self-descriptiveness*: a self-descriptive dialogue must be understandable through self-explanatory feedback from the system or is always available when the user needs it.
3. *controllability*: the user must be in full control of the pace and direction of interaction from the beginning until the task has been successfully completed.
4. *user expectations conformity*: a dialogue is accepted by the user when it is constantly agreeing and corresponding to the expected quality and needs of the user.
5. *error tolerance*: a dialogue tolerates errors if the goal is achieved with the least possible action by the user.
6. *suitable for individual*: individualisation deals with how the dialogue can be adapted to suit the skills and needs of the user.
7. *suitable for learning*: the dialogue must support the user in learning the system.

The look of the interface is classified as information presentation. Information presentation encompasses the organisation of information (including arrangement, grouping, labels and alignment) for the graphical display and for coded information. Information presentation has the following seven attributes as described by Maneva [90] and Katerattanakul and Siau [73]:

1. *clarity*: the content of information must be quickly and accurately communicated;
2. *discriminability*: the information displayed must be accurately distinguished in appearance;
3. *conciseness*: minimum possible information must be displayed;
4. *consistency*: the presentation of information must be consistent throughout;
5. *detectability*: user's concentration should be towards the required information;
6. *legibility*: the information provided must be easy and simple to read; and,
7. *understandable* : the meaning must be clearly comprehensible and recognizable.

This section discussed the four measurements that are used to structure UIs. It went on to discuss seven principles of dialogue requirements as taken from Oppermann [114] and seven attributes of information presentation. The following section discusses the general principles of UI design.

3.1.1 General Principles of User Interface Design

This section discusses general principles according to Mayhew [95], that need to be followed when creating UIs for any group of users. It presents twelve principles for UI design and discusses them separately.

1. Know the users.

A user case study is helpful at the beginning of every design [95]. A designer needs to know the following:

- the users' expectations and assumptions about the functionalities of the program;
- the UI paradigms that the users know;

- goals to be achieved by the users on the system; and,
- what errors the users might make.

In the context of this research, knowing the users allows designers to understand illiterate and semi-literate users' expectations and assumptions. This enables designers to design interfaces specifically for illiterate and semi-literate users. The results of a WOz experiment carried out to understand how illiterate and semi-literate users interact with computers are discussed in Chapter 5.

2. Use natural mapping whenever possible.

Natural mappings must be obvious and easily implemented. What seems natural can be confusing and in cases where natural mappings seem uncommon, it is necessary to use labels [95]. Labeling in cases of illiterate users might not be significantly helpful as the users are unable to read. It might, however, help semi-literate users. The use of localised mappings that users are familiar with is part of the study carried out in Chapter 6.

3. Do not allow users to engage in an action they are not supposed to do.

Do not let the UI allow the users to move forward while they do not have the necessary information needed. The interface should detect all errors and actions that are not allowed [95]. In cases where users are novices, allowing them to engage in actions which they are not supposed to do makes them panic when the result is not the expected one.

4. Avoid sounds in user interfaces unless absolutely necessary.

Sound can be annoying; if provided there must be an option to turn it off. Sound can be used in cases where users are illiterate or are visually impaired. In cases where the user has a particular "sound paradigm" they are expecting, the addition of sound is important (e.g. a click sound when a button is pressed) [95]. In this study, sound feedback was used to allow access to illiterate users who cannot read text.

5. Efficiency of operation.

User designs should take into account the number of screens and keystrokes or mouse clicks it takes to perform an operation [95]. The higher the number of screens and keystrokes or mouse clicks involved, the more confused novice users become and the more chances of them failing to complete a task. This is explained in Section 5.4.

6. Design for error.

Assume the users will make every possible error when using the interface. Try to keep the users from any errors as much as possible and if there are any errors that are detected, sufficient information must be provided about the cause of the error and what remedy can be taken. Designs must make it possible to undo any action that might cause an error. Almost all operations must be reversible [95].

7. The importance of feedback.

Immediately after an action, there must be feedback to show that something is happening [95]. When things are happening, there must be feedback after every second to show that progress is being made. When a cancel button is provided, it must be able to stop the action straight away when clicked [95]. As in principle three, novice users panic when they do not get feedback on an action, resulting in them thinking that they have carried out a wrong action. Detailed information on consistent feedback is given in Section 3.2.3.7.

8. Keep what the user must remember to a minimum.

The user does not have to remember what they did last so that they can carry out the next action [95, 105].

9. The Principle of Information Hiding.

Object-oriented programming for software design encourages the principle of hiding information. An interface should be designed according to the needs of users. These needs should be found in the use case analysis [105]. This principle supports principles one and three as it only allows the users to view the information that is necessary to them and allows them to carry out the required task.

10. Know the user's expectations from visual clues.

Some practices have already been accepted as standards by users. Changing the meaning of these practices will confuse the users [95]. For example, when users encounter underlined and coloured text, they usually treat it as a link to another page. Failing to provide a link would confuse the users when text is colored and underlined. When changing the meaning of a control from a legacy system, the designer should also make a radical change to the look and feel of the control. When using a common metaphor with which illiterate and semi-literate users are familiar, it must be used for the same purpose as in the real world. Metaphors for illiterate and semi-literate users are discussed in detail in Section 3.3.5.2 and Chapter 6.

11. The Value of Comparisons.

A compare function is sometimes useful when dealing with setting up large amounts of data [95].

12. Users should know their options on each display.

All possible actions at any point should be made clear to the user [95].

3.1.2 Principles of Display in User Interfaces

This section discusses the presentation of information on the interface. Unlike the previous section, this section focuses on how written information must be displayed. There are three principles of display in UIs:

1. The amount of information displayed must be controlled.

Displaying a large amount of information will clutter the display, while too little information might confuse and annoy the user. It is important to have a visible control for every major function [95].

2. Use lower case when possible.

The human brain reads lower case faster than upper case. Lower case must be used naturally as in written text. Upper case sometimes suggests that people are shouting [95, 105].

3. The interface must be consistent [82].

Consistency is one of the key aspects of usable interfaces. Consistency in *presentation* means that users should see information and objects in the same logical, visual or physical way throughout.

Consistency in *behavior* means that an object works the same way everywhere [82]. Behavior of interface controls should not change within or between programs. Users should not be surprised by object behaviors in the interface. Results of an interaction must be the same, so that users will not question their own behavior, but rather the product's behavior.

3.2 Design For Illiterate And Semi-literate Users

This section reviews literature on attempts to create UIs for illiterate and semi-literate users.

Most of our current computer applications deny access to illiterate and semi-literate users mainly because of the barrier caused by excessive use of text, including menus and the content of the document itself [96].

GUIs were initially developed to make the use of computer systems easier without the need to remember complex commands [145]. GUIs include different graphical objects such as icons, menus and windows [33]. An icon is a graphic image or graphic symbol that represents objects; it is usually accompanied by text to convey the information. Menus also provide the same functionality as icons but are placed on a menu bar and can be used to present many more options. Despite being a step in the right direction, GUIs rely heavily on text to signal their functions. As a result, illiterate and semi-literate users face difficulties in accessing services and functions implemented on most computers.

While basic computer concepts often seem natural to literate people, they can often be a challenge for novice users who have low literacy levels or who speak a language other than the one shown on the computer [145]. The use of a computer mouse, for example, seems intuitive to regular users but presents a challenge to first-time users coming from backgrounds where computers are scarce. The concept that icons are selectable is also foreign to people who are unfamiliar with computers. To assist illiterate and semi-literate users, icons should change when selected or hovered over. These changes might include increase in size, changing their borders or colour, being animated, etc [88]. Toyama, Sagar and Medhi [145] agree with the idea of changing shape or size of icons when hovered over as these changes alert the user to the interactiveness of the icon and, in most cases, draw the user's attention. Maiti, Dey, Samanta and Kharagpur [88] argue that a provision of enlargement of icons on mouse hover allows for icon clarity. Furthermore, selecting an icon using devices such as the mouse button, finger or a stylus is far more easier.

3.2.1 Background

According to Goetze and Strothotte [49], while reading is difficult to define, it can be described as "looking at something written or printed so as to understand the meaning" or "to recognise and understand the meaning of symbols, gestures, signals or communication". It is estimated that almost half the world's population is illiterate [28]. Due to their inability to read and understand, illiterate people are categorised as the information poor. Potential users who are illiterate are faced with difficulties in accessing services in developing countries, especially when trying to access necessary information vital for health and employment [49].

Many researchers and other international agencies are taking steps towards bridging the digital divide in developing countries by improving information access on the web through the provision of hardware. Combating information poverty, however, requires more than just solving a hardware problem by providing web terminals [49]. Designing methods and appropriate tools for people with low literacy levels must also be considered.

Deployment of interfaces from developed countries to developing countries has not been successful in most cases because of the mismatch between the intended environment the technology was primarily designed for, and the realities of the environments in which they are deployed [136]. Because there are large differences related to cost, power and usage assumptions, research on technology design tailored to the specific needs of developing countries is needed [136]. Many ICT initiatives involve the use of standard web-based forms or Window-based GUIs as the primary interface with the Internet for connectivity. The current GUIs were designed with a specific user in mind, one who is literate and uses a language with a written form. In the developing world, where users in many cases are not functionally literate and may be fluent only in a language without a written form, the use of the standard Window-based GUI becomes a daunting access barrier [136].

GUIs largely depend on literacy: they normally include textural components such as icon description menus and require the user to be able to recognise applications and file names.

These require the ability to read. Figure 3.1 shows an example of how most GUIs use text to convey meaning to users.

Figure 3.1: Use of text to explain the GUI used.[49]

In most cases, a user has to read the text associated with the icon to be able to recognise it. At the bottom right/left of the window in Figure 3.1, for example, there is a task bar that shows the name of the icon pointed to by the cursor.

With literacy rates of less than 50% in developing regions, traditional GUIs alone might not work for all [136]. One alternative recommended by a number of researchers is speech recognition and speech synthesis which does not require literacy and can be used for languages that have no written form. Toyama *et al.* [145] have suggested the need to use graphics, animation and speech. In line with their recommendation, our project aimed to see how these may be used.

According to Kamil and Hiebert [72], treating every user as illiterate has a negative impact on the potential benefits of text to semi-literate users. Text can help the performance of semi-literate users and their reading skill acquisition as it presents learning opportunities which are important for the maintenance of rudimentary reading skills. A text-based interface, augmented with other modalities, might cater for users of all literacy levels. Audio and images can replace text for illiterate users when needed and could ease the interaction with semi-literate users. According to Findlater, Balakrishman and Toyama [41], an audio and text interface can be beneficial to semi-literate users.

3.2.2 User Interface Design for Illiterate and Semi-literate Users

Several studies have been carried out to help illiterate and semi-literate people access information through the use of different types of interfaces. Past experience has shown that the use of pictures and speech in combination with text has a positive feedback on helping semi-literate people to read [49]. This section surveys prior work on using speech and pictures to convey meaning to users with low literacy levels.

Creating UIs for universal use is not a new field. In 1949, Charles Bliss built a communication system comprised of a set of symbols which were used to overcome language barriers. The symbols could be placed together to construct a meaningful sentence [91, 146]. The Lingraphica [140] system developed by Sacks and Steele in 1984 is another remarkable early work in the field of pictorial communication. Lingraphica was mainly designed for people with aphasia to enable communication. Using a database of "word-concepts" connected to icons, patients could drag the icons to storyboards and Lingraphica would translate these icons into speech and text.

Champoux, Fugisawa, Inoue and Iwadate [26] presented another interesting communication system in 2000 called CAILS (Computer Assisted Language System) based on a visual language for communication. CAILS was used to produce iconic message objects which may be presented to the intended recipient. The basic idea of the system was to allow an individual to compose a message using basic graphics.

In IBM researchers from the India Research Lab built a voice kiosk, a voice-based system that can be accessed by a phone to provide an easy to use and cost effective solution for illiterate people in rural areas. The information kiosk system was developed for users in rural areas to create and access locally relevant content and system tried to minimise the use of keypads to navigate or to input user information [3].

Another voice based kiosk is the Speech dialogue System (SDS) for agricultural information, developed by Plauche, and Prabaker [121] and evaluated with semi-literate users in rural Tamil Nadu, India. The system was designed in a way that was inexpensive for gathering necessary information through a simple spoken dialogue system. Data collection was added into the dialogue design by recording villagers from different villages during their day-to-day interactions. Each village had its own acoustic model because of the numerous dialects found in India [121]. Nasfors [107] developed a similar kiosk for an agricultural information service. The system was aimed at mobile telephone users and was deployed in Kenya.

Project LISTEN's (Literacy Innovation that Speech Technology ENables) Reading Tutor [104] and Scientific Learning's Reading Assistant [1] are two of the automated speech recognition tools that can be used to provide a guided reading experience for the user. LISTEN works by displaying a story on a screen and then listens to a child reading the story. The system helps when it detects a long pause or a misread word. When helping, it highlights the relevant word.

The Indian Language Text to Braille Transliteration (ILBT) system was designed by Dasgupta [14]. It provided a generic framework for the transliteration of Indian language texts to Braille. Importantly, the system could be used as a document reader for an Indian language as a user could select a particular text document to be read aloud.

The VoicePedia system was another speech interface [137] designed to mimic the web search experience. The system functions by asking the user to enter keywords for a search. The system then shows a list of titles of the top ten results from which the user can choose by repeating the title or saying the title number. After saying the title, the system navigates to the web pages required. The use of voice feedback can also be included. This can be associated with the movement of the mouse. When a mouse is hovered over an icon, word or a place, a voice can be used to give feedback to the user in form of an explanation. The explanation is proportional to the time the mouse is kept over the words: a short hover time means a short introductory explanation and a long hove time means a deep explanation. Video can also be used to help users understand how to interact with the computer [45, 131, 149]. To be effective, the video must show a step-by-step explanation of how to carry out a task. Voice can be included in the video [96].

3.2.3 User Interface for Illiterate and Semi-literate Users

Different types of UIs have been used to try and help illiterate and semi-literate users access information on computers. This section discusses nine such UIs, some of which have been used on their own and others in combination.

3.2.3.1 Touch Interfaces

The ability for novice users to locate points on the screen using a pointer has proven to be difficult. Pointing with a finger [76] has been shown to be intuitive. This is one of the strengths of touch interfaces. A study based on the use of touch screens by novice users was conducted at the Barnet CAB [76]. This study investigated how user's behavior is affected by their literacy level when using touch interfaces to search for and retrieve information. The results from this study showed that users with high literacy levels performed better in browsing the web and searching for information.

3.2.3.2 Use of Images

Significant work has been done on developing UIs that consist of detailed icons and images which do not need text to be understood.

According to Toyama *et al.* [145] and Prasad *et al.* [124], while the use of images and graphics can be of great help, not all images or graphics can be used effectively. Toyama suggests that the use of static hand drawn representations combined with voice feedback is the most effective. Users who are unable to read text can be aided by listening to another person reading the text to them or by the aid of pictures explaining the text. According to Goetze and Strothotte [49], pictures have the following advantages:

- They can be included in the text (as in elementary textbooks) to teach novices to read.
- It is possible to use a single icon to represent multiple words [88], as a picture can convey a message worth a paragraph of words.
- They might sometimes be used to summarise information delivered by the text .
- More recipients can be addressed by the same picture than a spoken or written language. Language directed at illiterate people depends on the country they live in while pictures might be understood by everyone.

Toyama *et al.* [145] created an interface for novice users who had insufficient computer skills and who were semi-literate and illiterate. Their interface includes icon pictures that are detailed enough to be understood without the aid of text. The icon does not need to be clicked to be selected; it can be selected when a mouse hovers over it. In other cases, the icons increase in size when hovered over. The main limitation of this system is that it was primarily created for job searching. However, the technology and associated principles can be used in many useful UIs.

Maiti *et al.* [88] argue that information is gathered and maintained on the Internet in a way that allows a limited number of digitally literate people to access it. They provided an interface for digitally illiterate people to seek information from the Internet, using a user-friendly iconic interface to cross the language barrier and make the Internet accessible to all users. Figure 3.2 shows the interface.

Figure 3.2: Iconic UI created by Maiti *et al.* [88]

The system works by selecting an icon from an array of icons displayed in the interface and automatically generating a query according to the selected icon. The query is then fed to a search engine and the search engine returns the results in text form. The text is then converted to speech using a Text-to-Speech engine. The architecture of the search cycle is shown in Figure 3.3

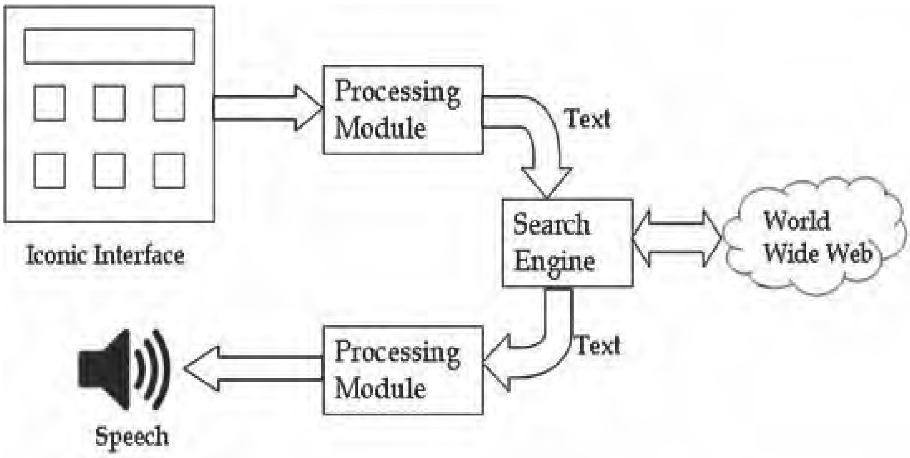

Figure 3.3: Architecture of the search engine developed by Maiti *et al.* [88]

Finally, a Virtual Media Enhanced Vocational Education Curriculum system developed by Bhavani, Rajamani, Bijlani, Achuthan, Sreedha, Nithyanandan, Rahul and Sheshadri [17] prompted users to identify themselves through a pictorial user name and password. This proved to be easy for users as pictures are easy to remember.

3.2.3.3 Action Graphic Representation

Different types of graphics can be used for representation; these range from real-world pictures to abstract cartoons, although semi-abstract cartoons are often used. Avoiding too generalised icons will minimise confusion as illiterate and semi-literate users do not visualise things in the same way as literate people. For example, when showing the direction of movement of cars on the road, Toyama *et al.* [145] suggested a car icon clearly pointing in the right direction rather than using an arrow which might not be affiliated with the car by illiterate users. When showing action activities such as washing, cleaning, cooking and drying, the icons for these actions must include a visual representation. For example, icons representing washing dishes could include water pouring on dishes. The icons must make it easier for illiterate users to understand the action being represented rather than assuming that they will understand.

3.2.3.4 Textless Interaction

A system is expected to work with the minimum possible text or no text labels, although there can be an option to enable some text markers. According to Toyama *et al.* [145], adding text to the interfaces might intimidate illiterate users; on the other hand, it can improve the reading skills of semi-literate users. Introducing text or adding text when the users are familiar with the interface might be beneficial to them.

3.2.3.5 Optional Use of Numbers

According to Toyama *et al.* [145], most people can read numbers regardless of their literacy level. In the system they created, there was an option that allowed the display of numbers on the screen.

3.2.3.6 Voice Feedback

In the system developed by Toyama *et al.* [145], most of the components within the GUI had voice feedback. In some situations, when a cursor passed or hovered over a control, a voice associated with the interface gave a brief or a long description of the control depending on how long the cursor stayed on top of the GUI. Prasad *et al.* [124] strongly supported the use of voice feedback. In their system, they found the use of pre-recorded human speech segments to be extremely valuable for illiterate users and therefore recommended the consistent use of voice feedback and help functions. The Electronic Screening Tool for Rural Primary Care experiment, by Akan, Farrell, Zerull, Mahone and Guerlain [5] used voice feedback to help illiterate patients store information on a database. Demographic information was collected using the speech interface and an eScreening system used Flash to develop a movie application to interact with users.

Walsh and Meade [148] created an e-learning system that used speech to tutor adults with low literacy levels. The system combined a multimodal interface of speech and visual interaction. Speech Recognition and Text-To-Speech were two of the speech technologies used to make web content available to illiterate students by converting text into speech. An investigation of both server-side and client-side technologies was initially carried out in an experimental prototype. Client-side technologies implement the conversion of Text-to-Speech or Speech-to-Text on the client while server side technologies implement these functionalities on the server. Results showed that client-side technologies were scalable and more efficient than server-side technologies [148]. It was also found that client-side technologies required less bandwidth compared to server-side technologies.

3.2.3.7 Consistent Help Feature

Consistent help features that guide and help novice users on how to use a system can help them to use it without assistance. A help feature that includes video and voice can be useful as the video shows users how the system works and the voice gives speech guidelines on using the system. In the job finder system developed by Toyama *et al.* [145], a help function was provided in three phases. The first help function was encountered by the user before using the system or just after beginning to interact with it. Different types of features were used: in some cases, video only was used; in others audio only was used, while in other cases, both video and audio were used. Every time an application was encountered, it was thoroughly explained to the user by one of the above-mentioned help features, including assistance in holding the mouse, carrying out mouse over icon actions, when and how to enable voice feedback and going into the next window. The system also consisted of a help feature at the control level. This provided information about almost all controls or icons in the application. For novice users, a pre-recorded video of human actors demonstrating how to use the control or icon was shown as an introduction to the application. This helped novice users understand the application and boosted their confidence in using it. The Virtual Media Enhanced Vocational Education Curriculum system, built by Bhavani *et al.* [17], provided a virtual environment that familiarised users with computers and interactive instructions on how to use the mouse. The system also used videos of demonstrations accompanied by animations, images and text to assist users.

The system created by Lobach, Arbanas, Mishra, Campbell and Wildemuth [86] was used to collect information from patients with low reading literacy levels and computer skills. The system successfully collected the information by adapting the human-computer interface of an on-line questionnaire to fit the computer skill level, mother-tongue language and the reading skill level of the user. The system used a series of instructional videos to give voice feedback. It was developed as a tool that could handle numerous questionnaires with different types of questions. The system was also designed to adapt to users with diverse aptitude levels. User aptitude levels, responses and questions were designed to be represented in numerous forms so as to allow scalability and accommodate new user aptitude levels, questions and responses. For example, the process of incorporating new information was carried out by simply adding a flag for the new information and the content of the questionnaire to the database.

3.2.3.8 Selection Options

Allowing the user to select options when using the application can also be helpful, depending on the level of literacy of the user [145]. For example, a click-less mode of interaction and other selectable GUIs may have an option to be selectable when the mouse hovers over them or by clicking a mouse.

3.2.3.9 Voice Annotation / Speech Feedback

Speech is one of the interfaces that is believed to help illiterate and semi-literate users access information. Sherwani, Tongia, Rosenfeld, Ali, Memon, Karim and Pappas [136] recommended the use of speech interfaces to allow illiterate users to access information, since the core technology of speech synthesis and speech recognition does not require literacy. Most people use speech to communicate, some may not be familiar with the written form of the language. Because of this, a lot of work has already been done on speech interfaces, from speech dialogue kiosks to telephone-based speech interfaces. This section discusses some of the work done that is relevant in the creation of UIs for semi-literate and illiterate users.

Plauche *et al.* [122] conducted a WOz experiment in three districts of Tamil Nadu with villagers of varying degrees of literacy. They found that first-time or novice users can go through a dialogue system using their voice irrespective of their literacy level or prior experience of computers.

Speech-based UIs have a cost advantage over other UIs as they are cheaper than display-based UIs [108]. They are also more accessible to illiterate and semi-literate users than text-based UIs. Despite these advantages over other interfaces, speech-based UIs have not yet been successful due to problems such as multilingualism, cultural and dialectal diversity and a lack of resources [21]. Cultural and dialectal diversity in particular are challenging for UI designers who need to understand the economic and cultural background of the user. Refer to Section 3.3.5 for more detailed information on cultural design.

Research by Findlater *et al.* [41] significantly impacted work on creating UIs for illiterate and semi-literate users. They created an audio and text system to evaluate the ability of illiterate and semi-literate users to transition from text augmented with speech to speech alone. In this experiment, they created an interface for both illiterate and semi-literate users to search for words from 40 Kannada words. Each word was paired with an audio button that caused the system to read the word aloud when the button was tapped. This system used audio feedback so that if users could not read, words were spoken back to them. Findlater *et al.*'s research showed benefits of using AUIs. Semi-literate users improved their reading skills and there was a lower error rate during the experiment while illiterate users were able to access information [41]. These findings were reinforced by Prasad *et al.* [124] who carried out an exploration of the feasibility of using a video-mail for illiterate users. They considered different message formats ranging from text, free-form ink, audio and video and audio. After the experiment, they concluded that the use of video and audio was best for illiterate users. Their main idea was to explore and create a usable application for illiterate users to communicate without requiring literacy. They designed and evaluated a prototype video-mail application that augmented graphics, animations and voice help to allow illiterate users to use the applications without any help from other people.

VoicePedia, a voice version of wikipedia, is another remarkable work on speech dialogue systems by Sherwani *et al.* [137]. This system enabled purely voice-based access to unstructured information on the web. Most systems focused on accessing structured information like movie show-times and stock quotes [137]. VoicePedia used a telephone based dialogue system for browsing and searching Wikipedia. The interaction with the system involved three phases:

1. *keyword entry* - in this phase, users spoke out search words one at a time; the system would repeat back the word so that the user could correct it or continue uttering the next word. After finishing entering all keywords, the users said "that's all" to move to the next phase.

2. *search result navigation* - the system would then search the web, using the search keywords before presenting a list of the first top ten results. These results were read aloud to the users who could select a search result by repeating the title, by saying the title number or by saying "that one" as soon as it was read to them.

3. *web page navigation* - after the results were selected, the system would fetch the corresponding page and parse it into extract page sections. All the section headings or titles of the chosen page were read to the users who could then choose the section they wanted to be read aloud to them. The users could also ask to search for a specific word in the page presented to them and VoicePedia would read aloud the line with the selected word.

The VoicePedia system was successful in developing countries as illiterate users could not type keywords or browse search results and webpages [137]. The results of this study showed that it is possible for an interface such a VoicePedia to be effective for information access on the web. Another finding was that keyword entry was faster through speech, although both search and page navigation were slower.

Although speech has been one of the most successful interfaces in allowing illiterate and semi-literate users access to information on the web, Naidoo and Barnard [106] argue that the use of Interactive Voice Response (IVR) systems is too technologically sophisticated for users in the developing world. Experiments focusing on user performance with regard to IVR telephone-based systems were carried out in semi-rural areas where users were unfamiliar with technology. Results showed that user's behavior was strongly influenced by human-human interaction [106]. This was evident from situations where some users would "chat" to the system, others would also question the system and when experiencing difficulties hearing the voice prompts, users would ask the system to speak louder [106].

According to Plauche *et al.* [121], dialectal variation, cultural barriers and multilingualism are other difficulties faced when designing speech dialogue systems.

This section discussed attempts to address access barriers by creating UIs that allow illiterate and semi-literate users access to information on computers. The following section discusses the incorporation of culture in the design process for creating UIs.

3.3 Ethnography/Ethnocomputing

According to Li and Karakowsky [85], people are what they have learned through their cultural background. Incorporating this into UI design will make it easier for users to understand the system.

The need for more transparent, flexible and efficient human-computer interaction for all users ranging from literate, semi-literate to illiterate users has increased. A growing interest in AUI design has emerged, trying to cater and allow access to all users. The main purpose is to achieve a simple interaction that has qualities and features similar to a natural human-human conversation, and to increase the strength of the interaction by using UIs that execute the same task in different methods or complementary UIs. New interaction patterns and guidelines that are culturally-relevant are necessary to bring about the design of AUIs that resemble human-human communication.

In a preliminary effort to establish the best AUIs for semi-literate and illiterate users, it is important to understand the specific requirements of the target group. According to Salber and Coutaz [132] , in cases where there are no generalisable theories and models, a WOz study is the most appropriate technique to identify the best design solutions. This gives the researcher a clearer picture of the requirements of the users for which the solutions are designed [132]. In a WOz experiment the user interacts with what appears to be an automatic system while in actual fact someone controls all the system's responses. Developers should be familiar with users' ways of thinking, including how they understand and act in the real world, their motivation, level of experience with the UI and their specific knowledge. Cultural background is also an important issue to be taken into consideration when designing a UI [49].

Designers need to take into consideration the history of how different cultural groups and societies interact with computers [143]. They also need to understand the general and fundamental problems of technological computing concepts in the situations in which they arise, as well as the problems and needs of the target group. Tedre *et al.* [143] emphasise the importance of examining and understanding the relationships between the target groups' natural way of living and computing technology. They argued that designers need to come up with new strategies and tools that are culturally relevant. The two fields of Instructional Design (ID) and Human and Computer Interaction (HCI) have been working on integrating culture into the design process by investigating the cultural differences that inhibit and encourage the design of culturally sensitive UIs [156].

3.3.1 Definitions of Culture

Many definitions of culture have been hypothesised by theorists and scholars [48, 60, 80, 153]. One widely used definition by HCI designers comes from Hofstede [64, 65], a cultural anthropologist. According to Hofstede [63], "culture is the collective programming of the mind that distinguishes the members of one human group from those of another. Culture in this sense is a system of collectively held values." To entitle the benefits of culture on UI design, designers must understand cultural features such as behaviors, the way in which objects are viewed in that society and the values of that particular group of people [75].

Scheel and Branch [133] provide one of the most widely used definitions in ID that encompasses the interdisciplinary perspectives of culture:

"....the patterns of behavior and thinking by which members of groups recognise and interact with one another. These patterns are shaped by a group's values, norms, traditions, beliefs, and artifacts. Culture is the manifestation of a group's adaptation to its environment, which includes other cultural groups and as such, is continually changing. Culture is interpreted very broadly here so as to encompass the patterns shaped by ethnicity, religion, socio-economic status, geography, profession, ideology, gender, and lifestyle. Individuals are members of more than one culture, and they embody a subset rather than the totality of cultures identifiable characteristics."

According to Banks [12], culture is defined as "*the ideations, symbols, behaviors, values, knowledge and beliefs that are shared by a community*". Culture is the way the group understands, uses and interprets the above artifacts, as they may be interpreted and used in different ways and for different reasons by different cultures.

Methods and theories like cultural diversity, cultural pluralism and cultural sensitivity [156] have been widely used by ID to focus on culture. *Cultural-diversity* refers to the numerous identities found within a certain society or group [16]. *Cultural-pluralism* is defined by Nieto [112] as the tendency of people to be loyal to their culture and language when living within a different culture. *Cultural-sensitivity* deals with how aware people are with differences and similarities in cultures and how these differences might affect their behavior, values and beliefs [156]. This study mainly focuses on cultural-pluralism and cultural-sensitivity.

3.3.2 Impact of the Roots of Computing on HCI

Computing's western origin is one of the major problems faced with Computer Science in developing countries [93]. According to Tedre *et al.* [93], users are forced to learn a new subject and a foreign way of solving problems. Other cultures are forced to learn Western ways of thinking in order to understand Computer Science. We argue that "universal" computing theories take different forms in different cultures.

Western countries are using globalisation to spread the Eurocentric philosophy of science to non-western cultures [93]. Most of the literature, teaching materials and methods used for solving problems are biased in favour of the traditional science of Western males [143]. Although the exploration of other cultures has enriched and equalised other cultures, there seems to exist a global consensus of the supremacy of western logic. The creation and maintenance of culturally sensitive UIs in Computer Science might decrease the digital divide as computing takes different forms in different cultures.

According to Tedre *et al.* [93], ethnocomputing refers to the "cultural perspective in the problem solving methods, conceptual categories, structures and models used to represent data or other computational practices".

Computing was initially designed to serve western society - mainly the army [11, 152] - and the sciences. Computing was used in the army for codebreaking, ciphering and ballistic calculations, and in sciences like chemistry, biology and meteorology. Computing evolved so that it could fit into the environment surrounding it. For a successfull adoption of Computer Science as a tool in other sectors of society, it adapted to the needs and changes of the western community and, as a result, adapting to the culture of that society. Only western culture was considered in the initial development of computers, with no support for other cultures, leaving other cultures unexplored [143].

3.3.3 The Construction of Science

Constructivists believe that truth and knowledge are not discovered by the mind but are created, and realities are socially and experimentally based [56]. Due to this, development is never done in a social or cultural vacuum because any form of knowledge is a human product, evolved socially and individually. Reality is shaped and stretched to fit the requirements of the community. The society is responsible for the shaping and development of ICT other than just adapting changes brought by ICT [143]. Societies with different cultural backgrounds have different knowledge that might help in broadening the understanding of different aspects of computer science. Current ICTs use metaphors that might have different meanings in other cultures outside the western world [143]. Learning and knowing are not just the passive storing of data in the brain but the mind processes the information, forming abstractions and concepts from the data [134].

3.3.4 Culturally Sensitive Learning

Computing as a whole is one of the most significant factors broadening the digital divide [143]. According to Castells [25], development is difficult without the Internet. He argues that "development without the Internet would be the equivalent of industrialisation without electricity in the industrial era" [25]. The only way to bridge the digital divide is to provide equal opportunity to computer education and making interfaces that allow access to all users. Studying ethnocomputing offers designers a multicultural approach to the designing of UIs. It recognises the influence of society and culture on understanding the use of Computers.

3.3.5 Cultural Design

Culture is always at the center of a design process when designing for illiterate and semi-literate users. Effective UI design should use the user's cultural experience as an index of their prior knowledge [38]. Young [156] argues that current methods applied in the inclusion of culture in design only serves a small part of what culture should in the real process of UI design.

Creating culturally sensitive UIs in the design of ICTs covers a broad scope, ranging from general to specialised design. General or culture-neutral design is classified under internationalisation which tries to get rid of culture so that the product is usable by all. Specialised or culture-specific design is classified under product localisation which tailors products to the needs of a certain target audience [67]. Due to the global marketplace, companies are now addressing the needs for many, hence designing general or culture-neutral designs. It is apparent that designing for international markets is a challenging task that requires more guidance. Trends towards internationalisation and localisation in HCI should have designers reconsidering the meaning of integrating culture in ICT designs. Another big problem is the gap between design and technology, as design is still behind. More detail on the internationalisation and localisation of UIs is discussed in Section 3.3.5.1 and 3.3.5.2 below.

3.3.5.1 Internationalisation of User Interfaces

Internationalisation aims at pushing the product to as many people as possible [10, 77]. Internationalisation eliminates cultural sensitivity, to make the product widely usable [67]. It seeks to develop a homogeneous product that can be used by people from different cultures. Aykin and Milewski [9] proposed suggestions, strategies and guidelines for culture-neutral web page design. These includes the following as described by Aykin and Milewski [9]:

- Eliminating culture-specific metaphors.
- Avoiding acronyms and abbreviations.

- Avoiding jokes, humour and idioms.
- Avoiding colloquial language.
- Avoiding gender-specific references.

3.3.5.2 Localisation of User Interfaces

Localisation is about including culture-specific design specifications and the creation of a specialised design for a specific target group. To meet the requirements of a target group, design specifications must be worthy of acceptance to that specific group. Ethnographic research can be one of the ways of authenticating a design. Ethnographic research studies culture and ways of life by observing participants, collecting data and interviewing them. These include field notes, videotapes, audio tapes and photography [40]. Designers should understand the target group in order to consider cultural variations when designing. Computer science should consider the cultural and social background of the target group.

3.4 Summary

This chapter discussed UI design principles, from general principles to principles of display. It also introduced the user study techniques that are used in the UI design process in section 4.1. The techniques discussed range from simple checklists to longitudinal studies and it has been shown that no single technique can suit all situations and needs. Attempts to allow access to illiterate users were introduced in section 3.2 while section 3.3 introduced the study of ethnography/ethnocomputing which deals with the integration of culture into the design process of UIs. The next chapter discusses the methodology that was carried out in this research. The methodology that was used placed the user at the core of the design of the interfaces so that designers were able to design localised interfaces for the target group. Because localisation of interfaces requires thorough knowledge of how users interact with computers, the methodology followed allowed the designers to understand how illiterate and semi-literate users interact with computers.

Chapter 4

Methodology

This chapter discusses and justifies the methodology that was used to develop guidelines for creating AUIs for illiterate users and semi-literate users. It discusses the user study techniques that were carried out in this research. It also discusses the user-centered design and the spiral model in Section 4.2.

4.1 User Study Techniques

Design is about exploring as many solutions as possible. It is also about usability as well as aesthetics. Meeting real users and real situations will have a major impact since the needs and wishes of the user need to be addressed right from the beginning of the design process. Designers need to get to know the user which is not generally accomplished by asking them what they want. The context in which the product will be used also need to be considered. The social situation of the user can also play a major role. Due to all these factors, it is important to investigate all aspects of the design problem. User studies can be used to understand the user needs, how users perform tasks and how everything fits into the context [46].

User studies are designed to obtain information on the interactions between the users and products. User testing involves listening and watching the users carefully. According to Dumas [35], the following eight principles should be followed when planning a users study:

1. *Set an objective*: specify what is being tested and what needs to be found out.

2. *Decide on the methods*: techniques and methods that must be used to gather information need to be carefully considered.

3. *Design tasks*: realistic tasks must be used. Task descriptions should be easy to understand without giving away information that will influence the results.

4. *Determine the setting*: the best setting for user studies is a real life situation similar to which the product is expected to be used.

5. *Decide what to be recorded*: decide which data should be recorded.

6. *Decide roles*: decide on the type of people who are needed to control the test (observers, test leaders etc.)

7. *Decide participants*: decide what kind of participants are needed.

8. *Prepare*: always do a pilot test to ensure that everything works before carrying out the proper user study.

Field studies are performed to understand what users do in a real setting. They consist of data collection in the field by interviews, apprenticeship and observations. The main advantage of field studies is direct observation [69]. Field studies are useful at the beginning as there will be a lot of uncertainty regarding user requirements. Large amounts of raw data can be collected. When carrying out a field study, the following ten steps should be taken into account:

1. A preliminary visit of the field to get ideas about the users, the context, their tasks, the environment and relations.

2. Decide on the user tasks to be observed.

3. List all observable behaviours.

4. Test the list.

5. Refine the list.

6. Carry out systematic interviews or field observations.

7. Try to get enough information.

8. Stop the experiment when you think you have enough information for designing the system.

9. Analyse and synthesise the results of the experiment.
10. Validate the results.

There are different types of user studies that can be carried out depending on the method to be followed. The following section describes some of the user study techniques that were carried out.

4.1.1 Checklists

Checklists are important for both evaluation and idea generation. Using checklist can save designers trouble and time [144]. They are a quick tool for evaluation. A small extract of a checklist for a map design is given in Table 4.1.

Characteristics	++	+	0	Necessary/ wanted
Accuracy		x		
Digital	x			
Analog			x	
Raster	x			
Coloured	x			
Detail-generalised				highly generalised

++ *very important*

\+ *important*

0 *unimportant*

Table 4.1: Small extract of a checklist for map design

4.1.2 Scenarios

Scenarios are stories focusing on the future. They move from the past to the future showing people's behaviour and preferences. They are stories with events, products, characters and environment. They include information about the context, users, the sequences of their actions and events. According to Carroll [24], detailed descriptions of how users accomplish tasks are important in design. Story telling helps focus on system issues and user needs. They show difficulties of the real world interaction with things. Scenarios help designers to think about numerous levels of interaction at once.

Observation of real people is needed to build scenarios on real situations and needs. Scenarios give room for investigation of a wide range of future designs and also result in an improved understanding. Scenarios investigates goals that the user may adopt and pursue. Figure 4.1 gives an overview of challenges and approaches in a scenario-based design.

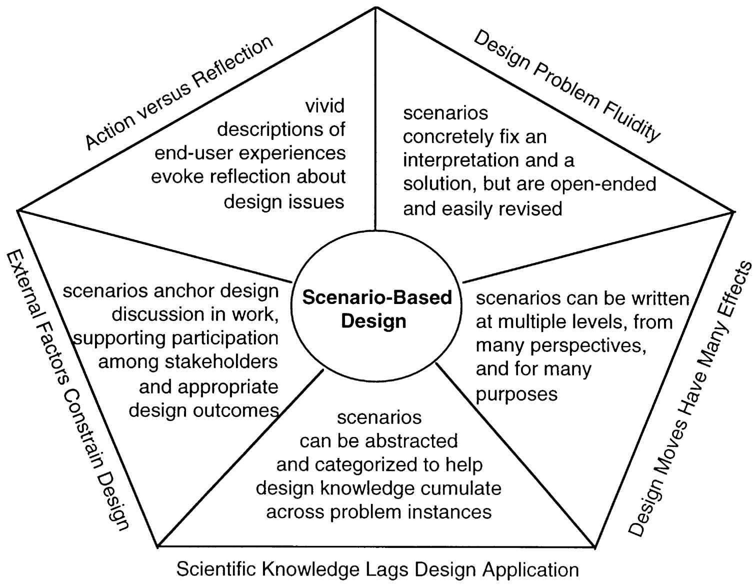

Figure 4.1: Challenges and approaches in scenario-based design [24]

4.1.3 Functional Analysis

Functional analysis focuses on the target group and purpose of use of the software. This information is essential for user interface design. Functional analysis has an advantage of finding new solutions to perform a task [15]. It is performed by a group of people who discuss the functionality of the product in question.

4.1.4 Empathic Modelling

As much as it is hard to become another person, designers need to put themselves in the position of the user at one point [123]. Empathic modelling aims to give the developer or designer a direct experience of the product [141]. It allows designers and developers to understand difficulties faced by users. This technique is normally used for users with impairment. Users with impairments often find it difficult to express themselves.

4.1.5 Questionnaires

Questionnaires are useful in collecting data in both exploratory and experimental user studies. Results obtained from questionnaires are similar to those from directive interviews. Developing questionnaires includes putting together right questions, ordering and formatting them correctly [29]. Questionnaires are relatively inexpensive to collect information. They can also be used online.

The following should be kept in mind when developing a questionnaire:

- Providing a clear statement of purpose.
- Carry out a pilot test to make sure questions are clear and there is space for responses.
- Decide how the results are going to be analysed.
- Questionnaires must be as short as possible.

A well designed questionnaire can be used to gather information on different aspects such as user demographics, performance, satisfaction, values and attitude.

4.1.6 Cultural probes

Cultural probes are used to explore discovery in the cultural dreams and meanings of people. According to Mattelmaki [92], probes foster design in four aspects:

1. dialogue
2. inspiration
3. participation, and
4. information

The first aspect refers to how probes foster social collaboration while the last three refer to the content. A probe may include a voice recorder, a disposable camera, a diary, tasks and questions relating to the study theme. To make the best from a cultural probe study, it is important to pay extra attention to choosing the participants and creating the probe package. Interviewing participants on the results from the probes and interpreting the results are equally important.

4.1.7 Diary Studies

Diaries have been used in the field of ethnography a lot. Refer to Section 3.3 for more detailed information on ethnography. In a diary study, participants are asked to keep diaries for recording their daily thoughts and activities [78]. A diary allows participants to express issues about their lives in a written form. In this study, dairies could not be used because participants were either illiterate or semi-literate and could neither read nor write. Diary studies requiring writing should involve people who are capable of expressing their thoughts in a written form. For visually impaired or illiterate participants, a voice recorder can be used. Although diaries were not used in this study, they are a good preparation for project-related interviews.

4.1.8 Brainstorming

Brainstorming is practised to generate as many solutions or ideas to a problem as possible. To be successful, designers must aim at generating more ideas. The more ideas generated, the bigger the chance of finding new solutions. It is important to explore ideas that seem not to make any sense at first, they may later prove to be valuable [115].

4.1.9 Interviews

An interview is one of the most traditional techniques for collecting information. Although interviews seem to be a straightforward process, there are many techniques that are useful for carrying out a successful interview. Interviews are normally carried out to gather information at the early phases of a design process. There are two types of questions that can be asked in an interview:

1. *Open questions*- questions that do not have a predetermined answer format.
2. *Closed questions*- questions that have a predetermined answer format (e.g "no" or "yes").

According to Robertson [128], some things are supposed to be avoided when carrying out an interview:

- Compound questions.

- Long questions.
- Jargon or any language that is not understood by the interviewee.
- Leading questions.
- Unconscious biases.

4.1.10 Cognitive Walkthrough

Most people tend to ignore reading manuals. In this study, targeted users were illiterate or semi-literate so they could neither read nor write. Cognitive walkthrough is a technique that takes into account novice users and the kind of problems they might encounter while learning to use the system. According to Wharton, Rieman, Lewis and Polson [150], designers will walk through the tasks, questioning themselves the following 4 questions:

1. will the user know how to carry out the task?
2. will the user notice the elements to use?
3. will the user understand the information on the interface?
4. will the user receive feedback after every action?

According to Gabrielli, Mirabella, Kimani and Catarci [44], cognitive walkthrough methods are quick to use and relatively inexpensive. Gabrielli *et al.* carried out a cognitive walkthrough supported with video data on a mobile-learning-evaluation.

4.1.11 Heuristic Evaluation.

Heuristic evaluation is an informal method of usability testing that was developed by Nielsen and Molich in 1990 based on their experience in consulting and teaching engineering [111]. It is an easy and fast method of recognising failures in user interfaces with respect to their intended purposes. Heuristic evaluation is simply looking at an interface and come up with an opinion about what is bad and good. Users are presented with an interface and asked to comment. According to Nielsen, an individual user can find atmost 51% of the usability problems in the interface. Section 6.3.1 gives more detailed information on the number of users that are recommended. Nielsen *et al.* [109] developed the following nine basic usability heuristics :

1. Simple and natural dialogue.
2. Use the language that the user understands.
3. Keep the user's memory load to the minimum.
4. Be consistent.
5. Provide feedback.
6. Provide shortcuts.
7. Provide clearly marked exits.
8. Prevent errors.
9. Good error messages.

4.1.12 Low-fidelity (lo-fi) prototyping

Lo-fi prototyping is characterised by an easy and quick translation of high-level design concepts into testable and tangible artefacts. It is sometimes referred to as low-tech as the implementation requires more time, a mixture of cardboard, post-it notes, paper, acetone sheets etc. According to Rettig [126], a designer working with lo-fi prototypes spend approximately 95% of the time thinking about the design and only 5% on implementing the prototype. Lo-fi prototyping maximizes the number of times you get to refine your design before you must commit to code. Prototyping was used in numerous design processes.

4.1.13 Bodystorming

Brainstorming is normally carried out in a meeting room while bodystorming is done for designs targeting mobile users. This is a form of brainstorming carried out in the real world, in context and includes the appropriate physical experience. Refer to Section 4.1.8 for more detailed information on brainstorming. According to Oulasvirta, Kurvinen and Kankainen [116], thorough appreciation of interactional, social, physical, and psychological contextual factors is important in the design process. Bodystorming involves carrying out design in the original context.

4.1.14 Focus Groups

Focus groups can be regarded as group discussions or interviews. End users participate in the discussion and at least one researcher acts as a moderator. Although focus groups may provide valuable input in the early stages of design, they are often carried out in places out of context. Best results are normally obtained when all users participate equally without a dominant participant who can influence other participants [102, 103].

Focus groups are used in wide variety of different fields of research. They are often used by sociologist and other disciplines including communication studies [6, 23], education [22, 42, 83], political science [31, 81], and public health [13]. Focus groups are also popular in other fields outside of academia like marketing [50, 54].

4.1.15 Workshops

Design workshops help to facilitate communication and increase the awareness between users and designers or developers [53]. A group of professionals and end users gather together allowing interaction to trigger ideas. Design workshops have been broadly used in the development of participatory design. They give participants a chance to experience new concepts and technologies. Normally workshops consist of different activities including discussions, generation of ideas and implementation of simple prototypes.

4.1.16 Informal Usability Testing

Although testing of UI is expected to be formally planned, there is also possibilities of carrying out an informal testing at the beginning of design [135]. This can be done in conferences and any other places when designers meet users. Early informal testing helps to give early feedback that can be valuable for idea generation. For the best outcome, encourage comments and be open to criticism.

4.1.17 Controlled Usability Test In The Lab

After conducting workshops, group discussions, interviews and other methods of gathering information, designers are likely to develop multiple versions of an interface or system.

Controlled usability test are performed when designers wish to determine the usefulness of the interface or system in a quantitative way [129]. This is achieved by making the user perform a set of constrained tasks. There must be at least two systems to be compared against each other on a number of performance metrics such as task completion, time taken to complete a task and number of errors. Refer to Section 6.2 for more detailed information on performance metrics. Statistical tools can be used to validate the results obtained from a quantitative test [55, 99].

Unfortunately a quantitative measure can only tell which system is better than the other but does not give details or reasons why it is better. A qualitative measure must be conducted in form of discussions or questions to determine participant's views.

4.1.18 Mobile Usability Tests in the Field

Controlled Usability testing deals with systems that assume a user would carry out a task in an office while mobile usability testing deals with mobile computing where users are expected to interact with the system while in motion. This involves carrying out user studies in real world scenarios [66]. The experimenter is still comparing at least two systems like in section 4.1.17.

4.1.19 Longitudinal studies

Numerous user studies only provide a short time of the usability of the system. This results in designers knowing more about the problems of novice users than the problems of experienced users [98]. Longitudinal studies are conducted to understand how usability problems change over time as users move from novice to experienced users [97, 120, 127].

4.1.20 Combining Techniques

User studies are an important part of user-centered design methodology [57]. The most appropriate technique depends on the stage of the design process. All techniques can be used for various purposes and in different stages of the design process. There is no single technique that suits all situations and needs. Due to this fact, a suitable set of techniques that fit well together should be found. The weaknesses and strength of all the above-mentioned techniques are summarised in Table 4.2. The table specifies how different user study techniques can be classified according to the following five dimensions:

1. Idea generation or evaluation: Evaluation/Ideas
2. Degree of user interaction between the designers and end users: Low/ Medium/ High
3. Realistic context: Yes/NO
4. Length of activity: Short/Medium/Long
5. Degree of technology required: Low/Medium/High

	Technique	I\E	UI	RC	Activity length	TD
1	Principles	Both	Low	N/A	N/A	Low
2	Checklists	Both	Low	N/A	N/A	Low
3	Personas	Ideas	Low	No	N/A	Low
4	Scenarios	Ideas	Low	Yes	N/A	Low
5	Functional	Ideas	Low	No	Short	Low
6	Empathic	Ideas	Low	Yes	Short/Long	Low
7	Cognitive	Evaluation	Low/Medium	No**	Short	High
8	Questionnaires	Both	Medium	No	Short	Low/High
9	Cultural Probes	Ideas	Medium	Yes	Long	Low
10	Diary Studies	Ideas	Medium	Yes	Long	Low
11	Heuristic Eva	Evaluation	Low/high*	No	Short	Low
12	Lo-fi	Ideas	Low/high*	No	Short	Low
13	Brainstorming	Ideas	Low/high*	Yes**	Short	Low
14	Bodystorming	Ideas	Low/high*	Yes**	Short	Low
15	Interviews	Both	High	No**	Short	Low/High
16	Focus Group	Ideas	High	No**	Short	Low
17	Workshops	Ideas	High	No	Short	Low
19	I.U.T	Both	High	No**	Short	High
20	C.U.T	Evaluation	High	No	Short	High
21	M.U.T	Evaluation	High	Yes	Short	High
23	L.S	Evaluation	High	Yes**	Long	High

I.U.T = *Informal usability testing.*

C.U.T = *Controlled usability test in the lab.*

L.S = *Longitudinal studies.*

Eva = *Evaluation.*

I\E = *Ideas generation or evaluation.*

UI = *Degree of user interaction.*

RC = *Realistic context.*

TD = *Degree of technology development needed.*

* *Depends on if end users are involved.*

** *Depends on where the activity takes place.*

Table 4.2: User study techniques overview

One important factor when considering techniques to use is the stage of design. At the beginning of a project, designers need to use techniques that help with exploring ideas and techniques that help with evaluation must be used at the later phases of the design. Some techniques are more aimed at idea generation while others are geared for evaluation [51].

4.2 User-Centered Design And The Spiral Model

In the initial stages of this project, a User-Centered Design (UCD) model was followed because it placed the users at the center as opposed to the UI. This allowed designers to pay special attention to the needs, wants and limitations of end users. UCD was also chosen because it allowed the molding of the UI according to users' needs and the ability to use it without forcing them to change their behaviour to accommodate the UI. According to Katz-Haas [74], UCD seeks to answer the following questions:

1. Who are the users?
2. What are the users' tasks and goals?
3. What are the users' experience levels with the UI?
4. What functions do the users need?
5. What information might the users need, and in what form do they need it?
6. How do users think the interface should work?

Answering the above questions allows designers to understand the users they are designing for. In this sense, UCD compliments the study of ethnocomputing which was discussed in Chapter 3.

Initially, literature on current UIs for illiterate and semi-literate users was reviewed. The review showed that while a lot of work had been done to enable illiterate and semi-literate users to access information on the web, there were no standard guidelines for creating AUIs. It also showed that UIs for illiterate and semi-literate users differ from one another according to the community they are designed for, so the kind of interaction illiterate and semi-literate users feel most comfortable with had to be considered.

The second step was to visit the Dwesa community and conduct a WOz experiment to understand how the users intuitively interact with computers. This is detailed in the Broad Understanding User Study in Chapter 5. The Dwesa community and some peri-urban areas around Grahamstown were chosen because large portions of these communities have either little or no experience with computers. A more complete representation of the sample population was covered by using both rural and peri-urban users. This study was able to determine their personal opinion of the most intuitive ways to interact with a computer, without being influenced by their prior experience with ICTs. As Section 5.3 will demonstrate, users preferred the use of speech and gestures. The study also found that users struggled to understand numerous GUI components, but struggled most with the tab metaphor which is used frequently across applications. As the speech and gesture findings mirrored findings from other researchers, the focus of the investigation changed to localising GUI components for semi-literate and illiterate users.

A second study was undertaken to compare the localised tab interface with a traditional tabbed interface. This study collected both quantitative and qualitative data from the participants. Quantitative data was collected in the form of error counts and time taken to complete a task, while qualitative data was collected in the form of user questionnaires after the user study. The user study found that users could interact with the localised tabbed interface faster and more accurately than its traditional counterparts. More importantly, users stated that they understood the localised interface component, whereas they did not understand the traditional tab interface metaphor. More detail is given in the Localised Tabs User Study in Chapter 6.

For the second user study, a spiral model similar to the iterative design model was followed, where UIs were created and tested in the Dwesa Community and peri-urban areas around Grahamstown to get feedback. The method was based on creating objectives, implementing them, testing, analysing and planning the next iteration. The feedback from the users was analysed and used to plan the next iteration of the design. The process was repeated until user issues were reduced to an acceptable level. The spiral model allowed designers to identify any problems that may arise in the UI. Figure 4.2 shows the spiral model.

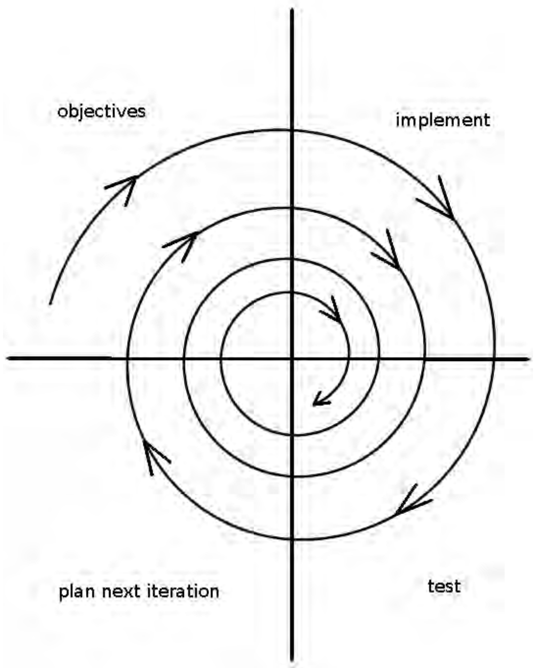

Figure 4.2: Spiral model

The following steps were followed in the spiral design model of the UI:

1. Create objectives of the iteration.
2. Implement the objectives.
3. After implementation, UIs created and presented to the target users for testing. Designers received feedback from the users and noted if there were any problems with the UI.
4. Results from the test were analysed and used to plan the next iteration.

The whole process was repeated until the UI was acceptable. The spiral went from broad to narrow as the project progressed: the research started with investigating guidelines for creating UIs for illiterate and semi-literate users and later narrowed to investigating the localisation of the tab interface metaphor after finding out that users were facing problems with the traditional tab interface.

With this methodology in mind, Chapter five can be seen as the first iteration of the spiral.

Chapter 5

Broad Understanding User Study

This chapter discusses the Broad Understanding (BU) user study that was carried out to understand how illiterate and semi-literate novice users interact with computers. It discusses the Wizard of Oz study that was carried out in peri-urban areas around Grahamstown. It goes on to describe the experiment's design and presents the findings of the study.

5.1 Wizard Of Oz Study

Many basic computer concepts that seem intuitive to computer literate people are a great challenge to new users, specifically those who are illiterate or whose mother tongue is different from the one used in the web browser. As an example, the use of a computer mouse presents a challenge to new computer users from backgrounds where computers are scarce. Also, the concept that icons can be pressed, clicked on once to select, clicked on twice to run and clicked on once with the right button to view more actions is not intuitive to people who are not familiar with computers. To create UIs that allow access to illiterate users, designers need to first understand how illiterate users interact with computers. This chapter presents the WOz technique that was used to understand how illiterate users interact with computers. As previously stated, the goal of this research is to enable semi-literate and illiterate users to access information on computers and to enable natural interactions between the user and the system. Collecting human-human interaction information through computers using the WOz technique assists in developing and fine tuning AUI to simulate such interactions.

A WOz experiment is a research experiment in which subjects interact with a computer system that they believe to be automated, but which is actually operated or partially operated by an unseen human being. According to Aist, Kort, Reailly, Mostow and Picard, the WOz experiment is a technique for designing interactive systems by replacing the "brains" of a yet-to-be-built computer program with a human wizard who pulls the strings from behind the scenes [4].

The wizard normally hides in another room and intercepts all communications between the user and the system. Sometimes this is done with the participant's prior knowledge; in this study, users were not told so that their expectations could be evaluated early in the design and their natural behavior encouraged. The system feedback was partly simulated by a human with the consequence that subjects were given more freedom of expression [59]. Dahlback, Jonsson and Arrenberg [30] argue the use of a wizard makes the WOz simulations difficult to run as humans are flexible and make mistakes, while computers are consistent; similarly, people are slow at typing while computers are fast. To speed up the feedback of the wizard, the wizard is not supposed to give all the responses that will be fed back to the user and the wizard's interface has to be well designed to make work easier [20].

At least two observers take part in a WOz experiment. The first observer sits with the user, and asks them to perform an interaction (for example, add an item to an online shopping cart). The user is given no instruction on how to perform the task; instead it is left up to them to decide how they think the task should be performed. Although the user interacts with the computer, all that happens is their motions are recorded while an unseen observer operates the computer. This allows researchers to capture the way the user expects an operation to be performed. The WOz experiment is a technique that can be used throughout the design process and across multiple technologies by inserting wizards at various levels of control as necessary to mimic a fully functional system [87].

The WOz experiment has been used in the creation of numerous dialogue systems. One of the systems where it was used was in the design of the Virtual Intelligent Co-Driver (VICO) spoken dialogue system. The system was designed to allow a driver to communicate with a virtual co-driver under harsh conditions in an automotive environment. The communication was through a conversational speech interface that allowed natural, user-friendly, safe and comfortable interaction [47]. The users were put in a room where they simulated driving while the wizard was in another room where he could see all the driver's actions through cameras. The wizard was also the virtual co-driver [47].

The WOz experiment was also used to collect data for the creation of a Spoken Human-

Computer Dialogue System for a driving situation by Cheng, Bratt, Mishra, Shriberg, Upson, Chen, Weng, Peters, Cavedon and Niekrasz [27]. Two divided rooms were set up: the subject room and the wizard room. This was designed so that the user and the wizard could not see each other. This design boosted the confidence of the users since they didn't know where the feedback came from.

According to Dybkjaer and Bernsen [36], the WOz experiment is used in a situation which is partially decoded by computers but understood by human beings leading to the direct interaction between the wizard "human being" and the user on the other end. They carried out a WOz experiment to determine the trade-off between naturalness and recogniser constraints in a speech dialogue system. They argued that a WOz experiment made it possible to test and design ideas and to gather knowledge of the system, its users and interaction before the implementation of the system [36]. A WOz experiment was used to collect information in situations where the set-up of the original experiment could not be tested in a conventional laboratory setting [89]. The application of the WOz method was used to test a ubiquitous computing system called Doorman [89]. Doorman is a system that uses spoken dialogue language input and multimodal speech output to control the access of people to a building. This system was tested by simulating speech recognition with a human wizard operating the fully functional system. Using the WOz technique, they also discovered that their current multimodal spoken output for guiding visitors was not successful and would need to be redesigned. One of the advantages of using the WOz experiment is being able to test the system before implementing it completely.

A WOz feasibility study was also used by Hudson, Fogarty, Atkeson, Avrahami, Forlizzi, Keisler, Lee and Yang [68] to explore whether and how robust sensor-based predictions of interruptibility might be constructed. The researchers were also interested in finding out sensors that are useful to carry out predictions and how simple the sensors might be. This search for a simple sensor encouraged researchers to carry out the WOz experiment [68].

In another scenario, the WOz technique proved to be useful in the study of the actual use of service robots with cognitive capabilities. One main problem is that service robots do not yet exist as a product and prototyping them is costly. A need to simulate robot interfaces to enable the study of ordinary users interacting with a service-robot led to the use of the WOz study [52]. Other work done in the field of artificial intelligence included the testing of a new design for an instructible intelligent agent called Turvy [94]. A WOz method was used to teach the simulated agent.

5.2 Design

This section gives an overview of the experiment set-up and the participants that participated in the experiment. It also includes the methods used and results of the WOz study.

5.2.1 Experiment Set-up

To carry out the WOz experiment, two desktop personal computers (PCs) were setup in two different rooms. The first PC was used by the participants and the second PC was controlled by the wizard. Figure 5.1 shows a picture of PC (A) and a participant.

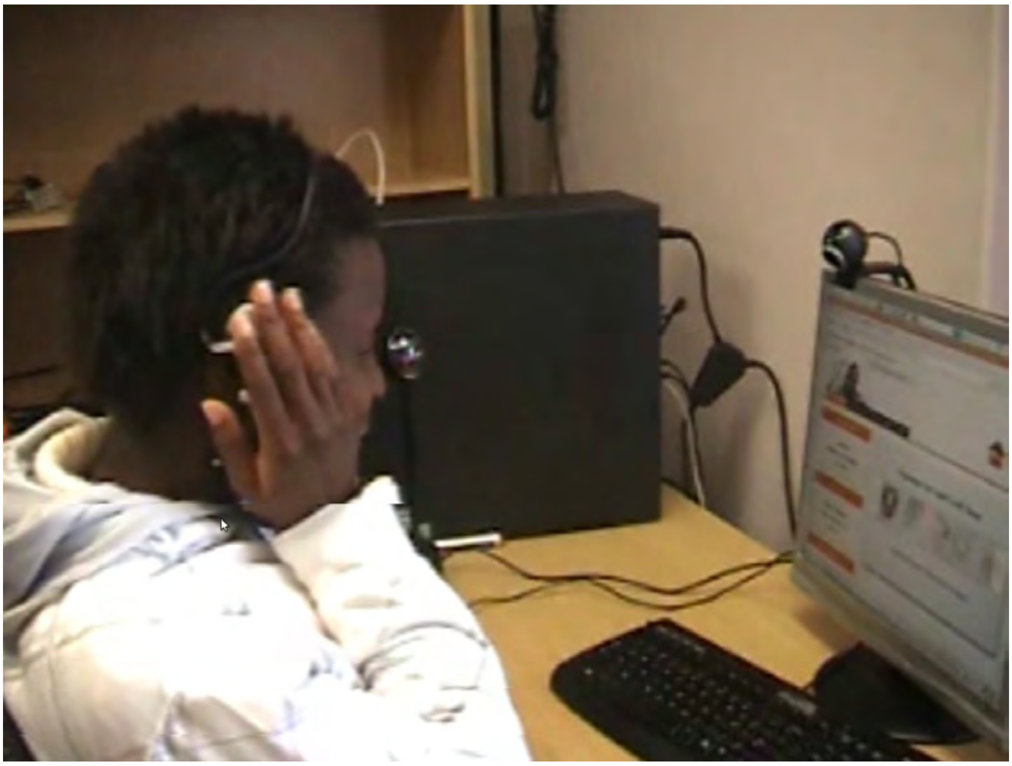

Figure 5.1: WOz study configuration

PC (A) had two systems installed on it that were created by Jakachira [71] and Dyakalashe [130]. The first system was an e-government system that allowed users to access information; send applications for identity documents (e.g. birth certificates and passports) to the government's databases; report any incidents to the police; and, other services. The second system was an e-commerce site with an online shop. The front-end of the system allowed customers to view and buy products. Owners of the shops had access to their online shops where they could update their stocks, upload new images of their stock and carry out general shop maintenance.

When entering the room, an observer gave the participant a set of headphones for voice feedback and a microphone for speech interaction with the system. The presence of the observer was important so that participants could explain what they were trying to do. The participant's PC allowed them to choose the mode of interaction with which they were comfortable. Three USB cameras and one digital video camera were set up to record the user's actions. In another room, a PC for the wizard was setup with two monitors. The wizard also had his own set of headphones to listen to the user's speech and a microphone to give voice feedback to the user.

Figure 5.2: Wizard watching the user's actions and giving feedback

The two PCs were connected through a 100Mb/s wired network. An additional USB camera was directly connected to the wizard's PC from the experimental room using a 10m USB cable. An IP camera was first used over the network but it proved to be affected by a delay of at least a second. The wizard controlled PC(A) by remotely logging in via a secure shell. This was used to remotely run commands on PC(A). Remote desktop viewing was used to allow the wizard to carry out interactions that were believed by subjects to be autonomous. Remote desktop viewing also allowed the wizard to view the participant's mouse movements and actions. Feedback was given through linphone clients that were installed on both PCs. Voice feedback was altered to sound as if it was generated by an IVR.

Four tasks based on the lexical level of the model of interaction developed by Foley, Van Dam, Feiner, Hughes and Phillips [43] were chosen. Foley *et al.* explain that all interactions performed by computer users can be broken down into six tasks which are:

1. Path - the ability to move the cursor by moving the mouse from one position along a list of positions.
2. Location - selection of objects from a set of currently existing objects.
3. Use of text - the ability of users to use text, entering text, etc.
4. Value - the ability to identify and use numbers.
5. Object Orientation - changing the orientation of objects.
6. Position – the user indicates a position on an interactive display often as part of a command to place an entity at a particular position.

Only four tasks from this model were tested. Object orientation and position were not analysed because there was no task on both systems that was suitable for testing these.

5.2.2 Participants

Using word of mouth, 16 participants were recruited from the Grahamstown community. Their literacy level was determined by asking them to read and fill in a consent form and a questionnaire. The consent form is presented in Appendix A. The level of literacy of the participants was determined according to the Flesch-Kincaid Grade Level. The results of the readability of the consent form are presented in Table 5.1.

Table 5.1: Consent Form's Readability Flesch-Kincaid Grade Level results

	Score
Passive Sentences	33%
Flesch Reading Ease	53.3
Flesch-Kincaid Grade Level	8.9

Table 5.1 shows that the Flesch-Kincaid Grade Level attained for the consent form was 8.9 which is supposed to be easily read by a student in grade 8. Participants who could not read and understand the consent form were classified as illiterate. Users who managed to read and understand the consent form with some difficulties were classified as semi-literate. Their computer literacy level was determined in a pre-test interview. This gave information on whether they were novice users or whether they had used computers before. The participants were placed in groups of four. A maximum of four people participated each day, one at a time. All the participants were illiterate except for two who were semi-literate. All participants had high numeracy levels (i.e. they all could count and identify numbers).

5.2.3 Approach

Participants were asked to interact with PC(A). When entering the room, participants were welcomed by an observer. Participants were asked to sign a consent form. The consent form was read and explained to them by the observer in cases were the participants were illiterate. The observer gave the participant a set of headphones for voice feedback and a microphone for speech interaction with the system. They were each given four tasks to complete.

Task 1: Finding a black-beaded anklet on the e-commerce system. This task tested how users interact with the system in terms of the location, path and value and how users deal with text.

Task 2: Finding the latest reports that were made on the e-government system. This task allowed the analysis of location, path, value and text.

Task 3: Finding ordered items that were delivered and finding out how much they cost. This task was also done on the e-commerce system. It allowed designers to understand how illiterate users deal with location, value, path and arbitrary text.

Task 4: Applying for a birth certificate. This allowed the analysis of all the components.

After performing the above four tasks, participants were asked to complete a questionnaire to evaluate subject satisfaction. Since most of the participants were illiterate, the observer read and explained the questions. Their responses were recorded using a digital camera and three USB cameras. The questionnaire is found in Appendix A.

5.3 Results

This section presents the findings of the WOz study. The findings include the results from the first trial run of the user study and the results from a full user study.

5.3.1 Pilot Study

A first trial run was undertaken to determine any problems with the user study. Participants performed the same tasks as in the full user study. In the trial run, feedback was given by the wizard in the form of: mouse move, text entry, voice feedback, gesture recognition (pointing gesture at the screen recognised as mouse move and selection). Participants were given no introduction to the system, but were simply asked to interact how they would like to. Initial analysis of their interactions showed that they did not know where to start with the system. To help participants, an audio introduction to the system was recorded and played at the beginning of the user study. This ensured that the same information was given to all participants. The introduction described the purpose of applications and briefly highlighted all the inputs available to the participants. As users first received output from the PC using voice, they tended to ignore all other input modalities and concentrated on using voice only. Users expected the computer to be supernatural machines that interacted purely on voice and processing information without being controlled by a human being. As a result, they just said out the name of the task and expected the computer to complete the task on its own. The introduction was then changed to a video and voice file. This video demonstrated how to interact with the computer system. Another finding of the trial was that illiterate participants could not use the keyboard because characters on a keyboard were designed for people who can read and requires a certain level of literacy to identify them. Almost all users could recognise numbers because they all had better numeracy skills.

The following subsection will detail the results of the actual user study. Results are described in terms of the four basic tasks outlined by Foley *et al.* [43]: path, location, use of text and value as described in Section 5.2.1.

5.3.2 Complete Study

The second study showed that semi-literate users had problems following the path from one tab to another. Computer illiterate people had difficulties following the path on their own. They had to rely on voice feedback. There were problems relying on voice feedback, because all the participants were first language Xhosa speakers, while the voice feedback was in English.

The arbitrary use of text was analysed in task 4 when users were asked to apply for a birth certificate. The main problem that was faced was reading through the document. One of the participants who could not take any action said “I can’t read and understand what is written on the computer, so I don’t know what to do”. After the addition of voice feedback, the same participant commented to the effect that “it is easy to use a computer when you are being told what to do, although the computer does not speak properly and it’s faster while it does not listen when you ask it to repeat itself”. Understanding what was required increased when voice feedback on mouse hover was introduced. The use of text interface alone proved to be a barrier to both semi-literate and illiterate users.

Task 2 was used to determine how illiterate users interact with numerical values. Participants were asked to look for delivered items, the amount, the number of delivered items and to enter the quantity. All users managed to identify numbers. All the users had a high numeracy level; they could all identify numbers from 0 to 9. One of the participants mentioned that “ I am used to reading numbers since childhood so numbers are easy for me to identify and I know the meaning of them”.

Locating icons and tabs on the desktop was not a problem to the users as they all pointed on the icons they wanted to be opened. One problem was understanding clickable or active items.

5.4 Analysis

Traversing from one page to another was a challenge since users were novices and had no idea about tabs, buttons, links and icons. Folders and icons act as interface metaphors that are designed similarly to how physical folders store other folders and files inside them. Illiterate users are not familiar with these metaphors as folders and files are normally found in office working environments. Metaphors that illiterate users are familiar with must be used. Cultural metaphors that people are familiar with and use on a daily basis might be of help. For example, using basket images or animations on tabs and folders might be of great help, as baskets are culturally used to store items. The metaphor must be something that is culturally used to store or keep something. To help users understand opening tabs, animations pouring out the contents of a page by tilting can be used. Some animations that show folders expanding or changing into the next page might also help users to understand the metaphor.

Another problem is that users are reluctant to scroll down the page. The following paragraph shows some ideas on how to help users understand that they have to scroll down to the information below the page:

1. the same picture of the icon can be used as the background of the webpage including the unseen part of the page so that the picture will be displayed half-way, showing that there is more information below.
2. if the interface consist of animations or pictures, the pictures should be partly displayed so that the user gets the idea that there is more content on the hidden side.

5.5 Summary

This chapter discussed results of a WOz study that was carried out to understand how illiterate users interact with computers. A review of the results of the user study that was carried out on 16 participants was given. Participants were given four tasks to perform on an e-commerce and e-government system. Their interaction with the two systems was analysed based on four tasks from the lexical level of the model developed by Foley *et al.* [43]: path, use of text, location and value.

Chapter 6

Comparative Study: Localised vs Traditional Tabs

The previous chapter discussed the WOz study carried out to determine the broad needs of the users as a first step in the spiral model. Based on the findings of that study, a culturally sensitive interface was developed. This chapter is regarded as the narrow phase of the spiral methodology which provides a comparison of this interface with a traditional interface and is divided into five sections. Section 6.1 discusses interfaces that were used in this study. Section 6.2 describes the performance metrics that were used for evaluating the above-mentioned systems. Performance metrics were used to carry out quantitative and qualitative analysis. Section 6.3 describes the tasks that were carried out on both systems. The tasks were the same as those used in the Broad Understanding user study in Section 5.2.1. This section also describes the users that participated in this user study, how they were chosen and the procedure that was followed. Section 6.4 describes the results from the user study that was carried out on both illiterate and semi-literate users. These results are presented according to the performance metrics discussed in Section 6.2. An analysis of the results is provided in Section 6.5.

6.1 User Interface Description

Two systems were used in this study; one of the systems employed a TTMI while the other system used a LTMI. Instead of using metaphors with which literate users are familiar, the LTMI used a basket metaphor, as baskets are traditionally used in rural areas for carrying and storage was used.

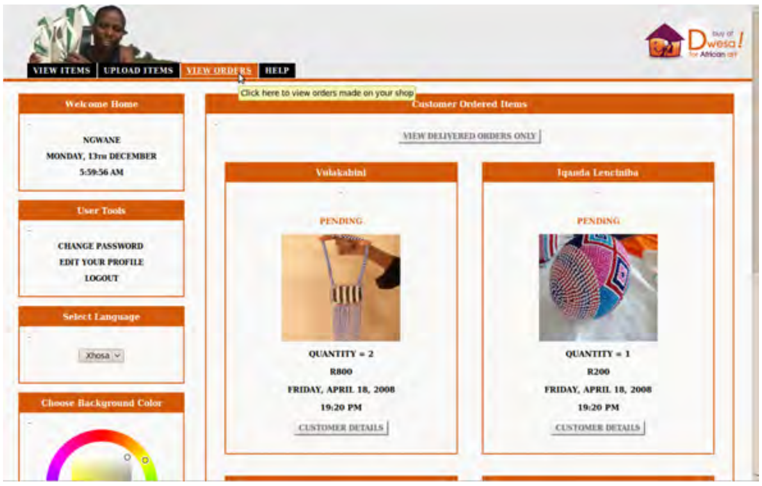

Figure 6.1: Interface for the TTMI

Figure 6.1 shows the TTMI that was used. Although symbols and graphics are present, text is still heavily used in the interface. Figure 6.2 shows the LTMI.

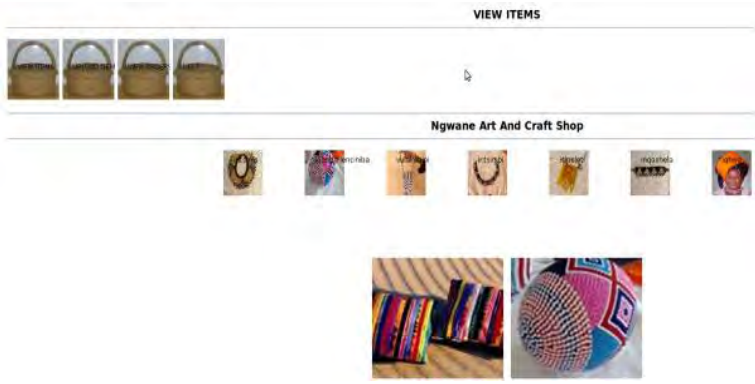

Figure 6.2: Interface for the LTMI

The LTMI system was localised to use basket metaphors on the tabs. The baskets were designed to tilt when a mouse hovered over it; in the process of tilting, a window linked to the specific tab slid down as though it was contained in the basket. Essentially, the window was a preview of the next page that would be shown when the basket was clicked. On removal of the mouse from the tab, the window slid back into the basket. Hovering over the basket also produced voice feedback, giving a short description of the next page to be opened. As a general rule, this design feature was applied to most of the icons and images on the interface. That is, the icons and images were designed to expand when hovered over and to produce voice feedback.

6.2 Performance Metrics

Palmer [118] and Bowman and Hodges [19] propose three performance metrics for a quantitative user study. These are: task completion time, task success and errors. These three performance metrics were used to compare the TTMI with the LTMI in this study.

Task completion time measures the time that the user is actively engaged with a system from the time he/she starts to interact with the system to the time he/she completes a given task [8, 109]. Time was measured in seconds and recorded automatically. Task completion time in this user study is important as it showed how fast users interacted with both systems.

Task success measures the ability and effectiveness of the user to complete the task given to them [58, 84, 154]. Task success was scored as a *binary* where 1 represented task completed and 0 represented failure to complete a task. The participant acknowledged completion of each task and this judgment was verified by the observer who checked the content of the final webpage visited by the participant. In cases were the participant declared success but the final page did not contain the required information, the task success score was adjusted by the observer to 0.

Errors in this study were counted as the number of mistakes made by the user while performing a certain task [7].

User satisfaction is normally measured by providing written questionnaires after carrying out a user testing [113]. In this study, written questionnaires were not feasible since the study was carried out on semi-literate and illiterate users. Questions were asked by an observer and users' responses were recorded. Questions asked included the following:

1. Which system were you comfortable using and what did you like on that system?
2. What is it that you didn't like on the other system?
3. What do you think needed improvement?
4. May you pass any general comments about both systems?

A complete list of questions can be found in Appendix A.

6.3 Tasks

As explained in Section 5.2.1, four tasks based on the model of interaction developed by Foley *et al.* [43] were used to evaluate both systems:

Task 1: find a black-beaded anklet.

Task 2: find the latest reports that were made to the government.

Task 3: find ordered items that were delivered and their cost.

Task 4: apply for a birth certificate.

6.3.1 Participants

Nielsen's research [110] shows the relationship between the number of usability problems found in a usability test and the number of users. Nielsen suggests the testing of at least 15 users to discover most (but not all) of the usability problems in a design. Nielsen also recommends using five users in a qualitative study and 20 users in a quantitative study. In this user study, 20 users participated: 10 illiterate and 10 semi-literate.

All the participants were first-time users from either a rural area or a peri-urban area around Grahamstown. Users who participated in this comparative study did not participate in other user studies carried out in this thesis. All users were computer illiterate as this study was aimed at comparing how novice illiterate and semi-literate users interact with a TTMI as compared to a LTMI. The users were of varying age from 18 to 50 years old; the average age was 31. Thirty-two users volunteered to take part in the user study; only twenty were chosen at random from the sample. The first step to choosing participants was to separate them into illiterate and semi-literate users by using the Flesch-Kincaid Grade Level.

6.3.2 Procedure

The experimental set-up resembled the one discussed in Section 5.2.1, except that there was no longer any wizard involved. All the apparatus were set-up in the same room.

Each participant was evaluated separately and given a brief explanation about the two systems. Each participant was asked to sign a consent form before participating in the study. The consent form, which was also used to determine the level of literacy of the participants according to the Flesch-Kincaid Grade Level, is presented in Appendix A. This is the same consent form used in the WOz study, described in Section 5.2.2

The Flesch-Kincaid Grade Level attained for the consent form was 8.9 which is supposed to be easily read by a student in grade 8. As in the previous study, participants who could not read the consent form were classified as illiterate. Those who could partially read the form were classified as semi-literate. Because participants were either illiterate or semi-literate, a second person read and explained the consent form to them. Participants were also asked for permission to record their actions and the recording of the user study for analysis. A sample of an agreement form granting the permission to record the user's actions is provided in Appendix A.

Each user was introduced to both systems by a video and audio file. The video demonstrated how to use the mouse, keyboard and other gestures that were available as explained in Section 4.5.1. Video was used to ensure that identical help information was given to all participants. To be certain that the user understood how these input devices worked, they were asked to click a next button to acknowledge that they understood. Clicking the button would take them to one of the systems, either the TTMI or the LTMI. Participants were not given time to experiment with any of the system to allow the capturing of how novice users would perform when presented with one of the two systems.

Participants were randomly grouped into four groups consisting of five participants each. This was done to prevent all the participants from carrying out the tasks in the same order. Random orderings were used to ensure that effects of learning did not interfere with user study results. Table 6.1 shows the order in which each group carried out the tasks.

Table 6.1: Order in which each group carried out the tasks

Task Order	Group A	Group B	Group C	Group D
1	*Task 1(LTMI)*	*Task 1(TTMI)*	*Task 2(TTMI)*	*Task 2(LTMI)*
2	*Task 1(TTMI)*	*Task 1(LTMI)*	*Task 2(LTMI)*	*Task 2(TTMI)*
3	*Task 2(LTMI)*	*Task 2(TTMI)*	*Task 1(LTMI)*	*Task 1(TTMI)*
4	*Task 2(TTMI)*	*Task 2(LTMI)*	*Task 1(TTMI)*	*Task 1(LTMI)*
5	*Task 3(LTMI)*	*Task 3(TTMI)*	*Task 4(LTMI)*	*Task 4(TTMI)*
6	*Task 3(TTMI)*	*Task 3(LTMI)*	*Task 4(TTMI)*	*Task 4(LTMI)*
7	*Task 4(LTMI)*	*Task 4(TTMI)*	*Task 3(LTMI)*	*Task 3(TTMI)*
8	*Task 4(TTMI)*	*Task 4(LTMI)*	*Task 3(TTMI)*	*Task 3(LTMI)*

The time taken on each task was recorded; all user actions were also recorded on a digital video camera. The recorded video was also used to quantify the participant's performance into time taken on task, errors committed and task success. After completing the experiment, the user was asked to give general comments about the two systems. They were also asked to rate the two systems on a scale of one to five, one being the best and five being the worst. The ratings were recorded to facilitate a qualitative analysis of the tabbed interface.

6.4 Results

The following sub-sections describe the results for semi-literate and illiterate users separately. It also compares the performance of illiterate and semi-literate users on both the TTMI and LTMI to test whether performance was influenced by the UI used or the level of literacy of the users. All the analysis in this section was carried out on a significance level of 0.05 (p=0.05). According to Bland and Altman [18], the standard level of significance used to justify a claim of a statistically significant test is 0.05. Within each user group the following results are presented:

- task success
- time-on-task
- number of errors
- subject satisfaction

6.4.1 Semi-literate User Results

This section will look at the task success rate, the time taken to complete a task, the number of errors committed and then finally subject satisfaction by semi-literate users.

6.4.1.1 Task Success

The first performance metric of interest was the task success on both interfaces. All semi-literate users were able to successfully complete their tasks resulting in an average task success of 1 for all tasks. As explained in Section 6.2, a binary metric was used for task success.

There was no difference in task success; all semi-literate users successfully completed the tasks assigned to them on both interfaces. There was no need to perform a one-way ANOVA test as there was no variance from the mean values.

6.4.1.2 Time-on-Task

Table 6.2 shows an overview of the results of the time taken on all the tasks carried out by semi-literate users on the TTMI. The table gives the mean values and standard deviation of all the tasks performed by semi-literate users on the TTMI.

Table 6.2: Time-on-task on TTMI by semi-literate users

TTMI	Mean(seconds)	Standard deviation (seconds)	Standard Error (seconds)
Task 1	118.60	41.75	13.20
Task 2	276.60	232.60	73.55
Task 3	341.00	31.32	9.90
Task 4	563.70	37.00	11.70
All Tasks	324.98	85.67	27.09

The average time taken to complete each task increased from Task 1 to Task 4 because the interaction required increased.

Table 6.3 shows the generalised results of the time taken to complete the same four tasks using the LTMI.

Table 6.3: Time-on-task on LTMI by semi-literate users

LTMI	Mean(seconds)	Standard deviation (seconds)	Standard Error (seconds)
Task 1	84.90	53.70	16.98
Task 2	142.90	98.00	31.00
Task 3	264.00	17.00	15.38
Task 4	410.00	11.00	3.70
All Tasks	225.45	44.93	16.77

Performance across tasks on the same interface was tested. A one-way ANOVA was carried out to statistically test any significant difference in the mean values recorded.

The procedure was to first test for any significant difference between the means of all four tasks performed on the LTMI. Each task was then tested against other three tasks. The results are presented in Tables D.1 and D.2 in Appendix D. There was no significant difference (p = 0.292) between tasks across interfaces for all except Task 3 (p = 0.026) in the LTMI. One possibility for having a significant difference with Task 3 was because it involved the filling in of a form, which was difficult for semi-literate users.

After establishing that there was no significant differences between the tasks across the same interface, a paired t-test for comparing tasks on the LTMI with TTMI was carried out as another form of verification. Table 6.4 shows the results of the paired t-test.

Table 6.4: Semi-literate TTMI vs LTMI paired t-test values

Semi-literate	t value	df	p value
Task 1	1.86	9	0.0096
Task 2	2.98	9	0.0158
Task 3	2.35	9	0.0430
Task 4	7.69	9	0.00003
All Tasks	3.72	9	0.1710

The results show that there is a significant difference in the time taken between TTMI and LTMI by semi-literate users on all tasks since all p-values are less than 0.05.

6.4.1.3 Errors

This sub-section discusses the errors that were committed by participants when they carried out the four tasks on both the TTMI and LTMI. All errors were counted and recorded per participant. A detailed description of an error in this context was given in Section 6.2. Means and variance were analysed using a one-way ANOVA to test for any significant difference between the errors committed. Table 6.5 shows the summarised results of the errors committed on the TTMI. Table 6.6 gives a summary of the results from LTMI.

Table 6.5: Summarised results of errors committed by semi-literate users on the TTMI

TTMI	Mean	Standard deviation
Task 1	4.40	2.63
Task 2	8.60	3.92
Task 3	9.30	2.50
Task 4	18.00	4.67
All Tasks	10.10	3.43

Table 6.6: Summarised results of errors committed by semi-literate users on the LTMI

LTMI	Mean	Standard deviation
Task 1	3.30	3.05
Task 2	5.10	2.90
Task 3	6.50	3.03
Task 4	10.50	3.47
All Tasks	6.350	3.18

Comparing the mean values of the errors committed on both systems, it is evident that the number of errors committed on each task on the TTMI were slightly higher than the mean values of the same tasks committed on the LTMI system. On average, 10.1 errors were committed across all tasks by semi-literate users on the TTMI compared to the 6.35 errors on the LTMI. A paired t-test was performed to test any significant differences in the mean values of the errors. Table 6.7 shows the results of the paired t-test. There was no significant difference found on both Task 1 and Task 2. A significant difference was found on Task 3 ($p = 0.02$) and Task 4 ($p = 0.03$). No significant difference ($p = 0.085$) was found when testing across all tasks.

Table 6.7: Semi-literate TTMI vs LTMI paired t-test values for errors

Semi-literate	T value	df	P value
Task 1	1.34	9	0.210
Task 2	0.71	9	0.080
Task 3	0.32	9	0.020
Task 4	2.31	9	0.030
All Tasks	1.17	9	0.085

6.4.1.4 Subject Satisfaction

Six out of ten semi-literate users preferred the LTMI system. They mentioned that it was easier to use. Five of the six users mentioned that the use of a localised metaphor was easy to understand as they were familiar with the metaphor and understood its use. They also mentioned that the preview of the next page was helpful as they could visually see what was on the page they were about to open. One participant said " when I saw a basket, I was curious to see what was inside it; that's why I hovered my mouse over the basket. After seeing that one of the baskets opened and produced something, I then started opening the other baskets".

The other four participants were comfortable using the TTMI system. They said that they enjoyed reading the labels used and could understand them. When they were asked on what needed improvement, most of them thought that combining the two systems would be helpful. One of the participant said " I prefer using the traditional tab metaphor interface but I also like some of the features that are provided on the localised tab metaphor interface such as previewing the next page".

The above subsection discussed the results of the experiment carried out on semi-literate users. It has shown that there was a significant difference in the time taken on task and errors committed but no significant difference in task completion. The following section explains the results from the study carried out on illiterate users.

6.4.2 Illiterate User Results

This subsection discusses the task success rate, the time taken to complete a task, the number of errors committed by illiterate users and subject satisfaction on both the TTMI and LTMI. Illiterate users followed the same procedure as the one followed by semi-literate users. They also carried out the same tasks carried out by semi-literate users on the same systems.

6.4.2.1 Task Success

The analysis of task success followed the same procedure as the one carried out on semi-literate users in Section 6.4.1.1 and also used a *binary* task success method. The results of the average values obtained from the number of participants who managed to successfully complete a task is shown in Table 6.8 (for the TTMI) and Table 6.9 (for the LTMI).

Table 6.8: Task success by illiterate users on the TTMI

TTMI	Mean	Standard deviation
Task 1	0.90	0.32
Task 2	0.10	0.32
Task 3	0.70	0.48
Task 4	0.00	0.00
All Tasks	0.60	0.37

Table 6.9: Task success by illiterate users on the LTMI

LTMI	Mean	Standard deviation
Task 1	1.00	0.00
Task 2	0.90	0.32
Task 3	0.90	0.32
Task 4	0.70	0.48
All Tasks	1.20	0.37

The results on task success on the TTMI shown in Table 6.8 illustrate that nine of the ten participants successfully completed Task 1. Only one person managed to complete Task 2, seven participants completed Task 3 and all the participants failed to complete Task 4 on the TTMI. Table 6.9 shows that on the LTMI all participants completed Task 1, nine participants successfully completed Task 2 and Task 3 and seven participants completed Task 4. This shows that illiterate users successfully completed more tasks on the LTMI than on the TTMI.

A one-way ANOVA was only carried out on Task 2 and Task 3, as Task 1 on the LTMI and Task 4 on the TTMI had no variances. Table 6.10 presents the one-way ANOVA results.

Table 6.10: One-way ANOVA on Task Success by illiterate users

ANOVA Illiterate Task Success	F value	df	P value
Task 1	0.00	0	0.00
Task 2	0.42	9	0.00001
Task 3	0.76	9	0.89
Task 4	0.00	0	0.00
All Tasks	0.60	9	0.12

As shown in Table 6.10, there was a significant difference ($p = 0.00001$) on Task 2 and there was no significant difference ($p = 0.089$) on Task 3. There was no significant difference ($p = 0.12$) observed when all the success tasks on the LTMI were tested against each other. It was also found that there was no significant difference ($p = 0.063$) when all tasks from the LTMI were tested against Task 1 and Task 3 from the TTMI.

This section discussed the task success carried out on both systems by illiterate users. It presented results from a t-test and a one-way ANOVA.

6.4.2.2 Time-on-Task

The results of the time taken by illiterate users to complete each task using TTMI and LTMI are presented in Table 6.11 and Table 6.12. In these two tables, Std dev stand for standard deviation while Std err stand for standard error. The results follow a similar trend to the results obtain by semi-literate users. All tasks carried out on the TTMI took a relatively long period of time to complete as compared to the time taken on the LTMI.

Table 6.11: Time-on-task on TTMI by illiterate users

TTMI (illiterate users)	Mean (seconds)	Std dev (seconds)	Std err (seconds)
Task 1	176.0	64.65	22.80
Task 2	186.04	0.00	0.00
Task 3	420.86	23.09	8.73
Task 4	0.00	0.00	0.00
All Tasks	261.1	43.87	15.77

Table 6.12: Time-on-task on LTMI by illiterate users

LTMI (illiterate users)	Mean(seconds)	Std dev (seconds)	Std err (seconds)
Task 1	138.50	62.66	6.99
Task 2	258.78	145.12	48.37
Task 3	363.00	19.59	6.53
Task 4	430.30	19.63	7.42
All Tasks	297.65	61.75	17.33

A paired t-test comparing tasks on the LTMI with the TTMI was carried out to test if there was any significant difference between tasks. Table 6.13 shows the results of the paired t-test.

Table 6.13: Illiterate TTMI vs LTMI paired t-test values

Illiterate Users	T value	df	P value
Task 1	1.98	7	0.088
Task 2	1.32	9	0.227
Task 3	3.48	9	0.043
Task 4	4.70	9	0.046
All Tasks	2.80	9	0.101

The results in Table 6.13 show that there was no significant difference on Task 1, Task 2 and the test across all tasks, but there was a significant difference on the time taken on Task 3 ($p = 0.043$) and Task 4 ($p = 0.046$) between the two systems.

A one-way ANOVA analysis to test the performance of tasks across each interface were carried out. The results, presented in Appendix D, show that there was no significant difference ($p = 0.12$) across all tasks on the LTMI. There was also no significant difference on the tasks carried out on the TTMI except for Task 4 ($p = 0.0017$). None of the users managed to complete Task 4 on the TTMI so a one-way ANOVA was not possible.

6.4.2.3 Errors

This subsection discusses the errors committed by illiterate users when they interacted with the TTMI and the LTMI system. The same procedure described in section 6.3.1.2

was followed. The overall error results obtained are presented in Table 6.14 for TTMI and Table 6.15 for LTMI.

Table 6.14: Summarised results on errors committed by illiterate users on the TTMI

TTMI	Mean	Standard deviation	Standard Error
Task 1	4.38	1.85	0.65
Task 2	6.00	0.00	0.00
Task 3	12.30	3.40	1.88
Task 4	0.00	0.00	0.00
All Tasks	7.56	2.63	1.27

Table 6.15: Summarised results on errors committed by illiterate users on the LTMI

LTMI	Mean	Standard deviation	Standard Error
Task 1	3.20	2.74	0.87
Task 2	4.67	4.18	1.39
Task 3	5.90	4.70	1.49
Task 4	11.43	2.88	1.09
All Tasks	6.3	3.63	1.21

A paired t-test was performed to determine any significant differences between the TTMI and LTMI. The results of the t-test are presented in Table 6.16.

Table 6.16: Illiterate TTMI vs LTMI paired t-test values for errors

Semi-literate	T value	df	P value
Task 1	1.98	9	0.08700
Task 2	1.21	9	0.02300
Task 3	0.96	9	0.00012
Task 4	3.01	9	0.00130
All Tasks	1,79	9	0.02800

There was no significant difference ($p = 0.087$) between Task 1 on both systems. There were significant differences with the rest of the tasks including the test across all tasks. A one-way ANOVA was performed on Task 1, Task 3 and across all tasks. It was not possible to perform an ANOVA test on Tasks 2 and 4 because of the absence of variance on both tasks. The results from the ANOVA have shown no significant difference ($p = 0.083$) on Task 1. A significant difference was found on Task 3 ($p = 0.0031$) and across all tasks ($p = 0.000014$).

6.4.2.4 Subject Satisfaction

All illiterate users were comfortable interacting with the LTMI. Eight out of the ten users mentioned that they could not understand the TTMI and preferred the LTMI. When asked how easy it was to use the system, they mentioned that it was self-explanatory. They preferred the use of localised metaphors, particularly the use of baskets (which they use for storage). One thing that was mentioned quite often by users was the positioning of the metaphor. When baskets are used for storage in homes, they are normally placed on top of kitchen units and other furniture so finding them on top of the page made them realise there might be something stored in them. The use of baskets caught their attention as they were familiar with baskets.

When they were asked what they thought needed improvement, some users mentioned that the page that was coming out of the basket was too big as compared to the size of the basket. When they were asked whether the size should be decreased, all participants opted for a bigger page. Some of the users wanted all the baskets to automatically open when a page is opened so that they could see what was in each basket before choosing what they wanted.

This section compared the LTMI with the TTMI. Results have been presented according to the performance of illiterate and semi-literate users separately. The following section presents results on how illiterate users performed compared to semi-literate users on both interfaces. Results on the TTMI are presented first, followed by the performance on the LTMI.

6.5 Discussion

Results on Task 1 from semi-literate users show that all users managed to interact with both systems and the time taken on Task 1 was relatively low as compared to the time taken to complete all the other tasks. The result was the same for illiterate users. Task 1, as mentioned in earlier, was to find a black-beaded anklet that was on the home page of both systems. This shows that illiterate and semi-literate users are comfortable with tasks that do not require scrolling down the page or navigating from one webpage to another. The time taken to complete the task on the TTMI system was relatively longer than the time taken on the LTMI because finding the anklet on the TTMI required the users to scroll through the art gallery provided; the arrows used for scrolling were not easily understood by the users. The other difference was the size of the pictures and their ability to expand so that they could be seen clearly. Only users who were familiar with the anklet could figure it out as the name and details were written in the TTMI while there was sound feedback speaking the details of the item in the LTMI. The above shows that presenting the required task on the same page without the need to scroll down makes it more intuitive to illiterate users The use of self-explanatory images without any text can also enables interaction.

Semi-literate users managed to carry out Task 2 on both systems although the results from the TTMI had a large variance that was close to the mean value obtained. This shows how difficult it was for some of the users to carry out the task. The task required users to navigate from one webpage to another and also required the users to be able to read the reports that were available. This required a lot of effort from the users. Users struggled with the TTMI as they did not understand how to navigate to another page and did not have the knowledge of what was on the next page, hence the large number of errors committed. Only one illiterate user managed to complete Task 2 on the TTMI; most of the users had no idea where to go and how to navigate to the required results. Nine out of the ten illiterate users successfully managed to complete Task 2 on the LTMI. The large success rate was because users could see the preview of the next page they were moving to and could get a description of the page and preview of the page.

Task 3 was successfully carried out by both semi-literate and illiterate users on both systems as it required finding images and symbols that were understood by the users. It was evident that both semi-literate and illiterate users were just moving from page to page looking for the images of the ordered items, hence the long time taken in achieving the goal. This means that the use of known symbols can be more helpful than just using text to represent the ordered items (as what is done in programs like Excel). Well-known symbols are easily recognised by semi-literate and illiterate users.

Task 4 required the filling in of a form. Users were required to navigate from the home page to the page where they were expected to download and fill in a form and send it to the government. All users were helped by an observer to read and fill in the form. All semi-literate users managed to carry out the task on both systems. Illiterate users could not complete the task on the TTMI system. Seven out of the ten illiterate participants managed to successfully complete the task on the LTMI where finding the form was easier for the illiterate users as they could easily preview all the available pages to find the one that had a form.

Results on the time-on-task by both illiterate and semi-literate users on the TTMI show that there was no significant difference in the time taken to complete a task by both users on the same interface. Results from the LTMI also show this. No differences were found on all tasks except for Task 4 that included the filling in of a form, which required a certain degree of literacy. This shows that regardless of the type of user, the time taken to complete a task was longer on the TTMI and shorter on the LTMI.

From all the tasks that were performed on both systems, it is evident that providing the required information on the same page, making it big enough to be recognised and not needing to scroll, makes it easier for users to interact with the system. Using symbols and metaphors with which users are familiar in their daily lives makes it easier for them to understand the system. The metaphors must also be positioned in a familiar way.

Text can be used with semi-literate users. Illiterate users, however, find text confusing and it can make them panic because they do not know the meaning of the text. The idea of just knowing that there is something written that they do not understand makes them lose confidence in whatever task they are trying to carry out.

This section discussed the results obtained when illiterate and semi-literate users interacted with the TTMI and LTMI systems.

6.6 Summary

This chapter has presented the results from the user study carried out on the TTMI and LTMI systems. Illiterate and semi-literate users interacted with both systems and a qualitative measure of their interaction was carried out according to the performance metrics described in Section 6.2. A paired t-test was carried out on each metric so as to determine any significant differences between the mean values and the variances of each task. These were used to carry out a one-way ANOVA to determine if there was any difference in the mean values obtained per task. A qualitative measure in terms of subject satisfaction was also carried out to determine which system was preferred by the users. The next chapter presents some guidelines for creating UIs for illiterate and semi-literate users that were developed from the literature from other researchers and the user studies that were carried out in this thesis.

Chapter 7

Guidelines For Creating User Interfaces For Illiterate Users

From results of the user studies carried out in this research, this chapter presents guidelines that can be used by developers to create UIs for illiterate and semi-literate users. The guidelines can be categorised into two main categories which are general page layout guidelines and voice input-output guidelines.

7.1 General Page Layout

There are nine guidelines which developers should consider when designing UIs for illiterate and semi-literate users. These are briefly set out below.

1. Page Layout

There must be consistency in page layout and length. Frequently used functions should not be placed deep in a menu structure. It was important in our study for the audio and video features to always be present on the page that illiterate users are on.

2. Speed of navigation

Speed of navigation is another major consideration for users [142]. When the connection is slow, poorly motivated users experience an increase in anxiety, even believing they could have done something wrong since most of them are unfamiliar with technology. Designers should try to prevent overloading websites with excessive images and embedded files because these might slow down the speed of the website. Feedback to the user must be given in cases where loading of pages is slow or might take longer than expected.

3. Ease of navigation

Ease of navigation should always be enforced in the design of a website [109]. More often than not, this means that the page layout should be kept simple; menu structure should be kept shallow; links should be well-highlighted with appropriate alternate tags; and, navigation aids that are often used should be permanently present. Simple language should also be used as this might be beneficial to semi-literate users.

Icons and graphics should be self-explanatory when being used as a link [49]. Speech should be clear and well-formed to ensure that illiterate users are able to understand. Text links should also be articulated in simple terms.

4. Use of self-explanatory icons

Self-explanatory icons must be used in a direct manipulation structure [49, 145]. Providing a rich graphical UI is important for illiterate users [91, 140]. Avoiding too generalised icons will minimise confusion as illiterate and semi-literate users do not visualise things the same way as literate people. A good example would be an illiterate car buyer understanding the relevance of a link with a picture of car. According to Toyama *et al.* [145] when showing the direction of movement of cars on the road, it is preferable to show a car icon clearly pointed in the correct direction other than using an arrow that might not be associated with a car by illiterate users. The use of images and graphics can be of great help but not all images or graphics can be used. Toyama suggested that the use of static hand-drawn representations combined with voice feedback is the best. Users that are not able to read text can be aided by hearing someone read the text to them or by the aid of pictures explaining the text.

Self-explanatory images were used in this research as metaphors in the localised tab user study. The results show significant improvement in the use of tabs as compared to traditional tabs.

5. Reluctance to scroll down

First-time users share one characteristic with experienced users: both novice users and experienced users are reluctant to scroll down the screen. Section 5.4 discusses the reluctance of users to scroll down and some ideas on how to solve the problem. While ensuring that the webpage fits on one screen may be helpful, the images on the page must also be sufficiently large and clear to permit users to easily scan and understand them. The whole webpage should be visually scanned with minimal scrolling [32].

6. Use of Digits

Digits can often be used as many users are numerically literate [145]. Results presented in Section 5.3.2 of the BU user study show that many people are familiar with numbers regardless of their literacy level.

7.2 Voice Input And Voice Output

When designing UIs for illiterate and semi-literate users, developers should consider the following seven guidelines regarding voice input and voice output:

7. Consistent help feature

A consistent help function should always be available [109]. Consistent help features that guide novice users on how to use the system can enable first-time users to use the system without assistance. A help feature that includes video and voice can be helpful as the video shows users how the system works,while the voice gives speech guidelines [96]. The video must show a step-by-step explanation of how to carry out a task [45, 131, 149].

8. Voice output

The use of voice output features that involve the use of pre-recorded text or speech generation technologies [41, 138] is important in translating text to speech so that users are able to understand the content. There are advantages and disadvantages to using either pre-recorded or speech recognition. Speech synthesis is considered far more efficient than recorded words, since the amount of data that has to be transferred over the bandwidth is a critical issue in web system design. Speech synthesis requires far less memory than pre-recorded audio files. On the other hand, speech synthesis generally generates inaccurate pronunciation. Another disadvantage of speech synthesis is that synthesisers are not available for many languages and dialects [32]. Pre-recorded words may be too slow in reaching the users of the system over the Internet, which will have disastrous effects on the usability of the system [142]. These effects also apply to speech synthesis when it is processed on the server side TTS technology. Results from the experiment carried out by Walsh and Meade [148] show that on average client side Text-to-Speech(TTS) technology was 17 times more efficient, in terms of bandwidth use, than the prototype that used server side. The other disadvantage of implementing on the server side is scalability.

Consistent voice feedback must be present, meaning that there should be consistency in providing voice-enabled content [136, 137, 145]. For example, every link should be able to generate a voice on mouse over.

9. Highlighting capabilities

Highlighting capabilities must allow the translation of speech to text for a certain portion of the content [145]. This is important for users to choose the content that is relevant to them.

10. Translation of Text

Translation of speech is important to users that speak different languages. Some of the users might not speak English, so the provision of audio or voice capabilities in a website becomes not only a matter of translating text to speech but rather translating text to a language that users are able to understand. Voice input features could be used to enable users to interact with the system [122]. Instead of just receiving information via voice output of the content, it is equally important for users to be able to use voice to perform tasks like filling in a form, performing searches, etc [1, 104].

11. Ability to playback voice

Users must be able to perform tasks like playback of speech, rewinding of speech, pausing speech, etc [79].

12. Alternate Text Graphic

Although it might not be applicable to illiterate users, it may be helpful for semi-literate users, if audible speech was played whenever users hover over a link [49]. While the system is expected to work with the minimum possible text or no text labels, there should be an option to enable some text markers. Toyama *et al.* [145] argue that adding text to interfaces might intimidate illiterate users. However introducing text or adding text when users are familiar with the interface might be beneficial to them by improving their reading skills. The system should be designed to allow users to decide the amount of text that is displayed.

13. Adding enhancements

Add minimal enhancements to provide full voice interaction. It is viable to provide added voice features for users. However, caution should be practiced to prevent major changes of the original website just to accommodate voice features for users. There should not be too much difference between the original system and the enhanced system. Add the enhancements so that they interact with existing mechanisms, use existing standards and use the same enhancements across markup languages. This is to ensure portability.

7.3 Summary

This chapter discussed guidelines that can be used to create UIs for illiterate and semi-literate users. These guidelines were developed from user studies that were carried out in this research.

Chapter 8

Conclusion And Future Work

To achieve the problem statement, this thesis aimed to investigate the following as stated in Section 1.2:

1. Determine the state of art in UIs for illiterate and semi-literate users.
2. Perform a WOz study to determine intuitive methods of interaction and identify current problems faced by illiterate and semi-literate users.
3. Design and evaluate localised solutions after identifying problems.
4. Design guidelines for creating AUIs.

To determine the state of art in UIs for illiterate and semi-literate users, a literature study was conducted. To conduct a literature study on the target group, two sites were chosen as a representative to the underdeveloped areas of South Africa. These two sites are the rural areas of Dwesa and peri-urban areas around Grahamstown and are discussed in Sections 2.1 and 2.2 respectively. The study has shown that people from these communities have previous experience with traditional ICTs (radios, television and newspapers) and modern ICTs (cellphones). Traditional ICTs are common and cellphones are the most prevalent modern ICT in rural areas.

The introduction of computers to these communities has posed several challenges due to the current interfaces. As explained in section 2.3, connectivity, affordability and capability are the three factors widening the “digital divide”. Although connectivity and affordability can be solved by providing computers, electricity and the Internet, capability remains a challenge due to the low literacy levels in these communities. Section 2.3 showed the difficulties faced by users in rural areas of developing countries.

A literature study on current user interfaces and previous attempts to allow access to illiterate and semi-literate users was carried out to check the state of the art in UIs for illiterate and semi-literate users. It has shown that current UIs were designed with a specific user in mind; a user who is literate. Current UIs rely heavily on text to signal their functions. This denies access to illiterate and semi-literate users. A detailed discussion is given in Chapter 3. Section 4.1 list most of the user study techniques that can be used. It went on to describe the strength and weaknesses of each technique showed that no one technique can suit all needs and situations. Combining techniques gives the best results. A combination of this techniques was used to follow the methodology discussed in Chapter 4.

General principles of UI design and principles of display in UIs were given in section 3.1. Section 3.2 showed that a lot of work has been done to try to allow access to illiterate users, semi-literate users and users with impairments. Textless interfaces have been developed to allow illiterate and semi-literate users to access information on computers. The interfaces range from touch interfaces, use of images, action graphic representations, textless interaction, voice feedback and consistent help functions. A detailed description of these interfaces and how they have been used is given in Section 3.2.

After a literature study on the state of the art in UIs for illiterate and semi-literate users, a WOz study was carried out with participants from peri-urban areas around Grahamstown to determine how illiterate and semi-literate users interact with computers. In the pilot study, participants were presented with an interface and were asked to interact with the computer in whatever way they thought would be possible. The pilot study showed that illiterate users could not use the keyboard because characters on a keyboard require a certain level of literacy. A complete study followed the pilot study. The experimental set-up and tasks were the same. Most of the results from the complete study mirrored the findings of other researchers. However, the problem faced with traditional tab metaphor interfaces was also highlighted in the WOz study. The results are presented in section 5.3. A detailed description of the experimental set-up is given in Chapter 5.

One of the goals was to design and evaluate localised solutions after identifying problems from the WOz study. A localised tab metaphor interface was therefore developed involving a tilting basket that produced a preview of the next page. This was tested against the TTMI as detailed in Chapter 6. Four performance metrics were used to compare the two interfaces: task success, time taken, number of errors committed and subject satisfaction. Results show that both illiterate and semi-literate users interacted faster with fewer errors on the LTMI. More participants were able to complete the given tasks on the LTMI than on the TTMI. Subject satisfaction also showed that users were comfortable working with metaphors with which they are familiar. Refer to Section 6.4 for more detailed information on the results.

The last goal of this research was to design guidelines for creating AUIs. By combining results of the user studies with the findings of other researchers, Chapter 7 presents guidelines that can be used by developers to create UIs for illiterate and semi- literate users. The guidelines were categorised into two main categories which are general page layout and voice input-output guidelines. These are presented in section 7.1 and 7.2 respectively.

8.1 Future Work

This thesis described some preliminary investigations into culturally relevant UIs. This work could be extended to intelligent interface agents that adapt to the user according to their literacy level.

Although illiterate and semi-literate users can now access and retrieve information on the web, filling in forms remains a significant challenge. This can be extended by combining localised tabs and speech engines.

This thesis can also be extended to the comparison of the use of isiXhosa and English explanations in the video, audio and text used.

Different localised tab visualisations may also be tried out in addition to the basket metaphor.

User study techniques such as brainstorming, bodystorming, focus groups and workshops as explained in Section 4.1 can be carried out with illiterate and semi-literate users to generate icon metaphors.

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Part I

Appendices

Appendix A

Forms (Consent and Questionnaires)

Consent Form

Project Title: Augmented User Interfaces for Access for Illiterate and Semi-literate Users

Researchers: Takayedzwa Gavaza, Dr. Hannah Thinyane, Prof Alfredo Terzoli

- I have received information about this research project.
- I understand my involvement in this research project.
- I understand that I may withdraw from the research project at any stage.
- I understand that participation in this user study is done on a voluntary basis.
- I understand that video and audio recordings of this experiment are going to be kept and referred to at a later stage.
- To the best of my knowledge I have no physical impediments that will stop me from completing this study.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

Name of participant ....

Signed Date ....

I have provided information about the research to the research participant and believe that he/she understands what is involved.

Researcher's signature and date ....

Questionnaire For The Broad Understanding User Study

Project Title: Augmented User Interfaces for Access for Illiterate and Semi-literate Users

Researchers: Takayedzwa Gavaza, Dr. Hannah Thinyane, Prof Alfredo Terzoli

1. How easy is it to use this system?
2. How effective could you complete the tasks and scenarios using this system?
3. How comfortable were you using this system?
4. How easy was it to learn to use this system?
5. How easy was it to find the information you needed?
6. Was the information provided for the system easy to understand?
7. Do you like using the interface of this system?
8. Does this system have all the functions and capabilities you expect it to have?
9. Overall, are you satisfied with this system?
10. What do you think needs to be changed?

Appendix B

Nielsen (Usability problems found vs number of test users)

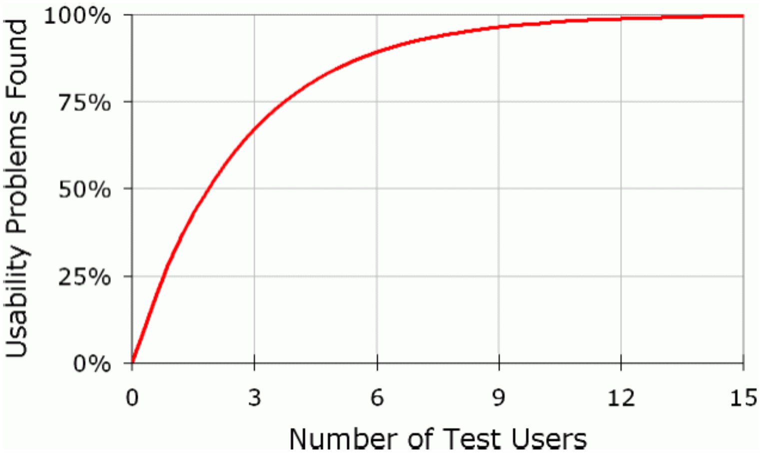

Figure B.1: Usability problems found vs number of test users [110]

Appendix C

Graphs (Box and Whisker Diagrams comparing the tasks carried out on the TTMI and LTMI.)

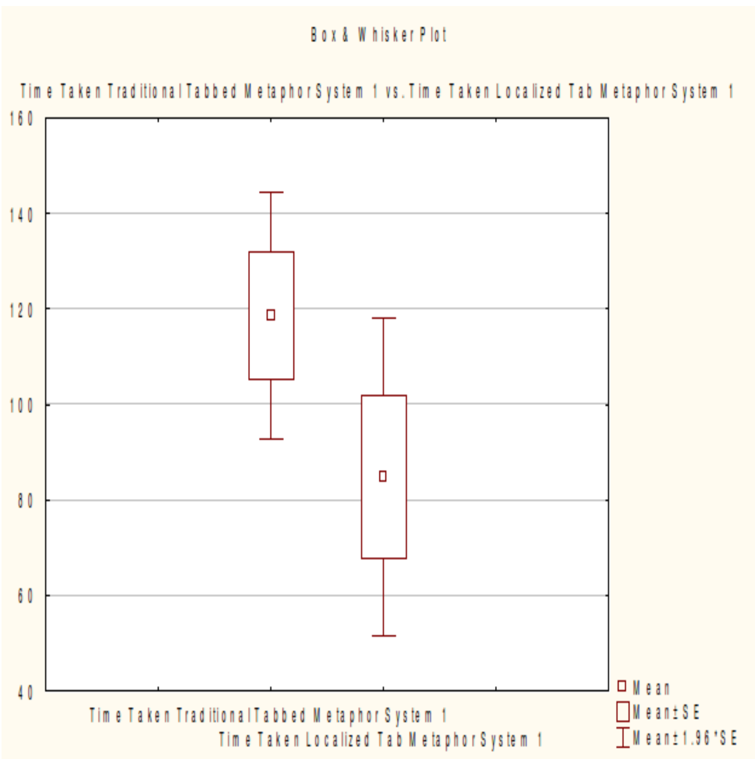

Figure C.1: Box and whisker illustration for task 1 TTMI vs LTMI by semi-literate users

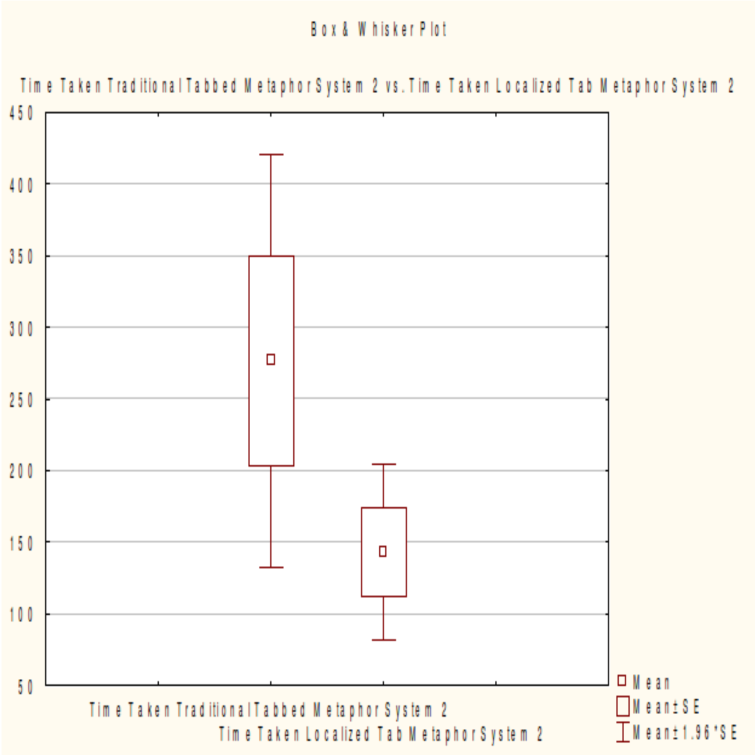

Figure C.2: Box and whisker illustration for task 2 TTMI vs LTMI by semi-literate users

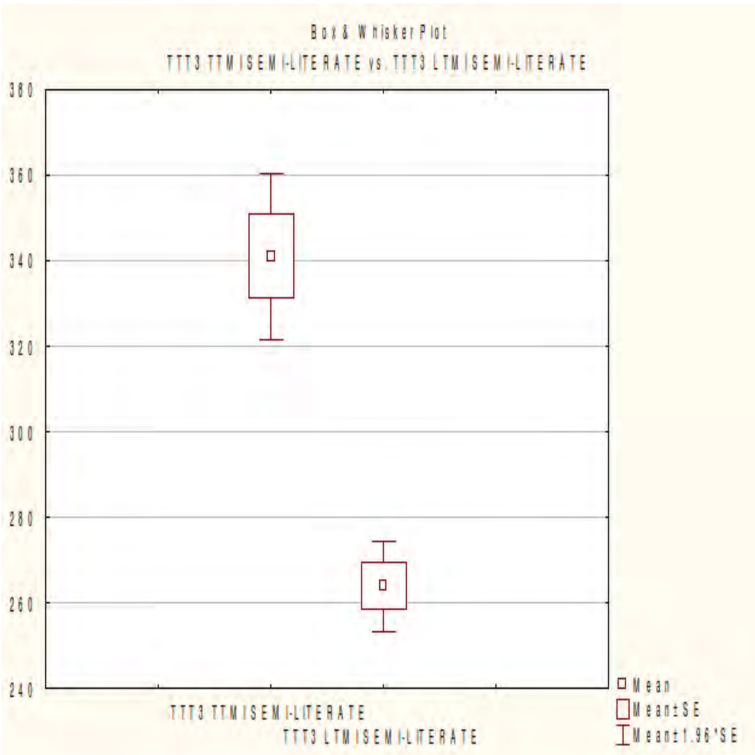

Figure C.3: Box and whisker illustration for task 3 TTMI vs LTMI by semi-literate users

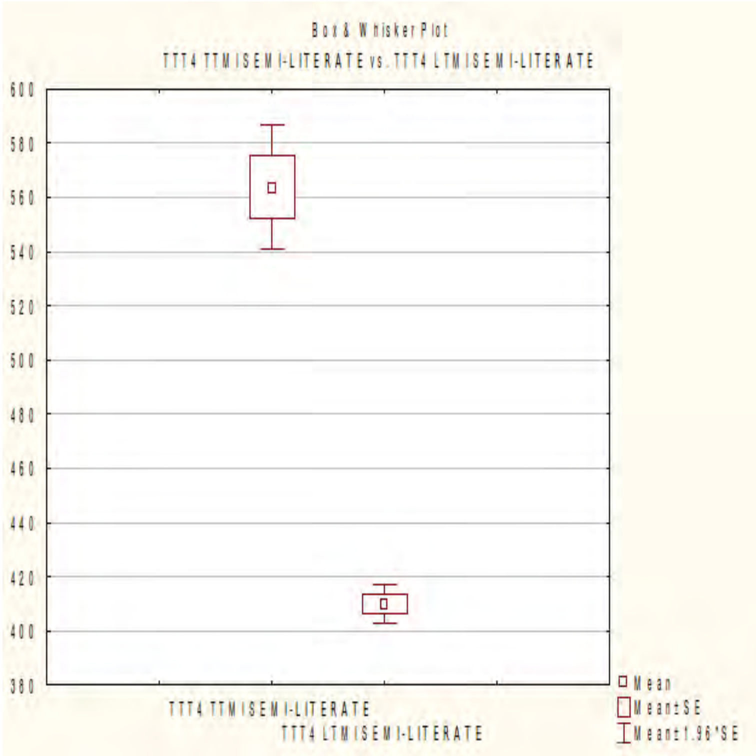

Figure C.4: Box and whisker illustration for task 4 TTMI vs LTMI by semi-literate users

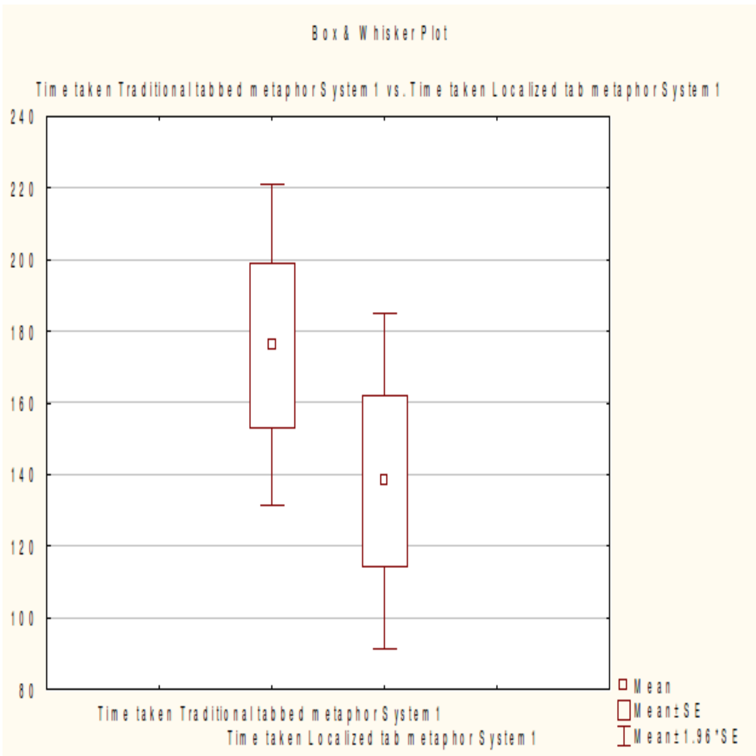

Figure C.5: Box and whisker illustration for task 1 TTMI vs LTMI by illiterate users

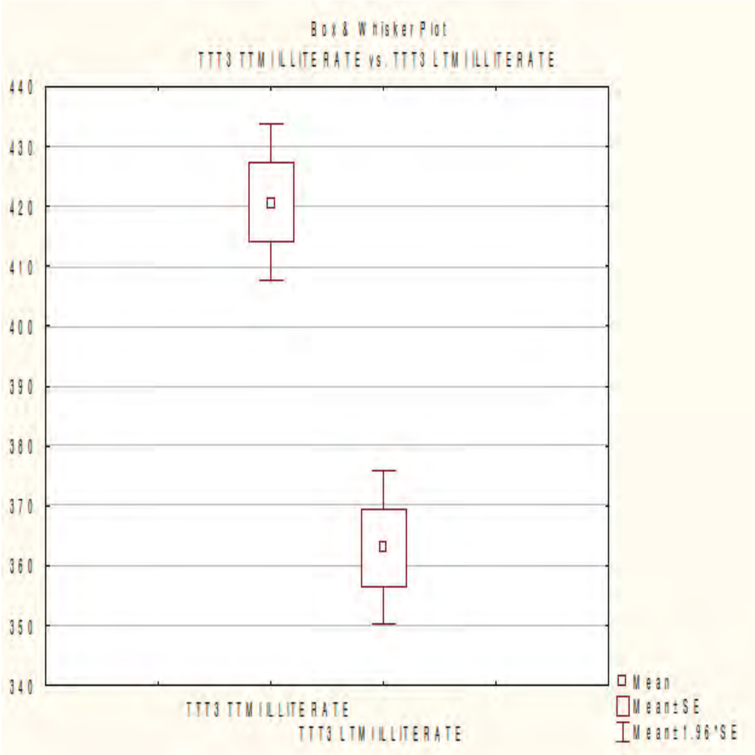

Figure C.6: Box and whisker illustration for task 4 TTMI vs LTMI by illiterate users

Appendix D

Tables (Results from the one-way ANOVA)

Table D.1: One-way ANOVA findings on the tasks carried out on the LTMI by semi-literate users

LTMI	Task 1		Task 2		Task 3		Task 4	
	f-value	p-value	f-value	p-value	f-value	p-value	f-value	p-value
Task 1			6.61	0.292	0.51	0.8	2.97	0.42
Task 2	6.61	0.292			0.262	0.914	0.831	0.695
Task 3	0.51	0.8	0.262	0.914			341.2	0.042
Task 4	2.97	0.42	0.831	0.695	341.2	0.042		

Table D.2: One-way ANOVA findings on the tasks carried out on the TTMI by semi-literate users

TTMI	Task 1		Task 2		Task 3		Task 4	
	f-value	p-value	f-value	p-value	f-value	p-value	f-value	p-value
Task 1			4.17	0.42	0.83	3.76	0.31	0.42
Task 2	4.17	0.312			0.8	0.41	0.413	0.95
Task 3	0.42	0.83	0.8	0.41			4.21	0.42
Task 4	3.76	0.31	0.413	0.95	4.21	0.42		

Table D.3: One-way ANOVA on the errors committed on the TTMI (Semi-literate vs Illiterate Errors)

ANOVA TTMI Semi-literate vs Illiterate Errors	f value	df	p value
Task 1	27.10	9	0.15
Task 2	0.00	0	0.00
Task 3	0.26	9	0.91
Task 4	0.00	0	0.00
All Tasks	9.24	9	0.68

Table D.4: One-way ANOVA LTMI errors (Semi-literate vs Illiterate)

ANOVA LTMI Errors (Semi-literate vs Illiterate)	f value	df	p value
Task 1	1.20	9	0.47
Task 2	0.79	9	0.66
Task 3	0.19	9	0.94
Task 4	2.89	9	0.21
All Tasks	1.30	9	0.52

Table D.5: LTMI Task success (Semi-literate vs Illiterate)

LTMI Task Success (Semi-literate vs Illiterate)	t value	df	p value
Task 1	0	0	0
Task 2	1.00	9	0.33
Task 3	1.00	9	0.33
Task 4	1.96	9	0.07
All Tasks	1.32	9	0.24

Table D.6: One-way ANOVA LTMI Semi-literate vs Illiterate users Time-on-Task

ANOVA LTMI Semi vs Illi Time on Task	f value	df	p value
Task 1	85.9	9	0.37
Task 2	80.3	9	0.07
Task 3	20.6	9	0.000114
Task 4	228.08	9	0.32
All Tasks	103.72	9	0.081

Table D.7: One-way ANOVA LTMI errors (Semi-literate vs Illiterate)

ANOVA LTMI Errors (Semi-literate vs Illiterate)	f value	df	p value
Task 1	1.2	9	0.47
Task 2	0.79	9	0.66
Task 3	0.19	9	0.94
Task 4	2.89	9	0.21
All Tasks	1.3	9	0.52