Developing a model to design and implement computer user interfaces in rural communities, an exploratory study

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Declaration

I, Delene Heukelman, hereby declare that all material in this dissertation is either original or suitably referenced.

I also certify that the dissertation has not been submitted for a degree at any other university and its only prior publication was in the form of the following conference papers:

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Student (Ms Delene Heukelman) Date

APPROVED FOR FINAL SUBMISSION

Promoter (Professor Oludayo, O. Olugbara) Date

Dedication

I would like to dedicate this to my late husband Frederik Nicolaas Heukelman who always encouraged me to achieve my goals.

Acknowledgements

I would hereby like to acknowledge the contributions made by the people who encouraged and supported me throughout this incredible journey. Firstly I would like to thank Dr. Marie de Beer, who pushed, pulled and did what she had to do to get me moving to start with the research and always encouraged me. I would like to thank my late mentor Dr. Daan van Vuuren who never failed to inspire me. Thank you to all my colleagues who patiently listened to all my deliberations about the obstacles I encountered. Thank you to Prof. Eyono Obono, who provided frequent new insights. I would like to especially thank Prof. Olugbara for picking me up and walking me through the final stage. Thanks to my children who never gave up hope that this research will be completed. I praise God for giving me the opportunity and helping me make a difference in the lives of many people.

Promoter: Professor O.O. Olugbara

Co-promoter: Professor S.D. Eyono Obono

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List of Abbreviations

AIC	Akaike Information Criterion
AVE	Average Variance Expected
BIC	Bayesian Information Criterion
CAIC	Consistent AIC
CFA	Confirmatory Factor Analysis
CI	Community Informatics
CoI	Communality Index
FA	Factor Analysis
FIMIX-PLS	Finite Mixture Partial Least Square
GoF	Goodness of Fit index
HCI	Human Computer Interaction
HCICI	Human Computer Interaction Concrete Icons
ICT	Information and Communication Technology
LVs	Latent Variables
LSR	Least Square Regressions
MIMIC	Multiple effect indicators for multiple causes
MVs	Manifest Variables
MFA	Multiple Factor Analysis
MLA	Multiple Linear Regression
EN	Normed Entropy statistic
OLS	Ordinary Least Square
PA	Path Analysis
PCA	Principal Component Analysis
PLS	Partial Least Square
Q^2	Predictive relevance
RI	Redundancy Index
R^2	Coefficient of determination
SEM	Structural Equation Modelling
TAM	Technology Adoption Model
TSM	Technology Support Model
UML	Universal Modelling Language

List of Synonyms

Variable, factor and construct are used interchangeably in data analysis and results reporting to mean the same meaning.

Icon and metaphor are used interchangeably throughout the thesis.

Segment, class and category have the same semantic.

Abstract

This thesis reports on original exploratory study that is aimed at contributing towards understanding of factors that influence Africa users support for alternative object metaphors for user interface icons. One of the great impediments for efficient utilization of information systems is the existing gap between system designs that typically follow western cues for crafting user interfaces and actual users who use those systems within their diverse cultural frames. The problem remains important because of the wider penetration of information systems, which serve as modern technology tools to improve service provisioning worldwide. In order to overcome the problem of optimum utilization of information systems, previous studies have proposed culturally adaptive user interfaces. The basic principle behind culture adaptive interfaces is to develop intelligent user interfaces that can automatically adapt to user contexts. However, the challenges with the new proposals for adaptive user interfaces are how to best model information about users, how to access the cultural background of individual users and empirically examine the effects of culture on user interface preferences.

In order to properly contribute to solving these problems, an exploratory study was conducted to empirically establish African rural users support for alternative village object metaphors, examine effects of culture on user support and investigate response characteristic among culturally diverse user groups. The synthesis of bodystorming and cultural probes methodology was applied to engage the participation of African rural users in the study. Technology support model was developed to measure user knowledge, comprehension, skills, performance and support for alternative African village metaphors as interface icons. The partial least square analytic modelling technique and finite mixture path segmentation model were used to test a set of research hypotheses and detect heterogeneity in 71 respondent data generated. Experimental results of this study show that human cognitive factors of technology knowledge, comprehension and performance influence African users support for alternative village object metaphors as interface icons. However, skill factor is not found to influence user support for alternative African village object metaphors. The factor of culture is found to moderate the effects of comprehension on user support and effects of user performance on user support. This study also identifies three segments of African users that result in heterogeneity within the inner path model.

Chapter 1 Introduction

This thesis reports on an exploratory study that aimed to explore the challenges of developing, designing and implementing computer user interfaces that are suitable for use in rural communities of Africa. The development of locally relevant Information and Communication Technology (ICT) systems for rural communities in the developing countries of the world has attracted the attention of some researchers (Chetty et al., 2004; Parikh and Lazowski, 2006; Das, 2010). In particular, it has long being known that designing, developing and implementing human computer interfaces is inherently difficult, time consuming and an easy solution does not currently exist, not even in the near future. The user-centric participatory design approaches and methods such as action research, bodystorming and cultural probes (discussed in chapter 3) have been recommended in the literature for the design, development and implementation of computer based systems (Chetty et al., 2004; Kimaro and Titlestad, 2008). Participatory design is generally regarded as an effective methodology in systems development to overcome inherent challenges such as changing contexts, difficulties of capturing the requirements of users and problems of achieving user acceptance of the final systems because users are engaged in the design process. However, user participation is often associated with certain contextual assumptions with their origin in the western countries that are not always immediately applicable in low income countries (Kimaro and Titlestad, 2008).

This study assessed the effectiveness of alternative African village metaphors towards contributing to the improvement of usability of ICT systems for African rural users. The design of Human Computer Interaction (HCI) Concrete Icons (HCICI) for African users, especially for those who reside in the rural settings, where accessibility to ICT is at a meagre and people lack contextual human cognitive properties such as computer skills, lack of infrastructures and lack of quality ICT education and training, requires the understanding of the cultural preferences of these users. The HCICI provides limitless opportunities for the improvement of ubiquitous use of ICT. Although some initiatives from both research and business perspectives to improve the usability of ICT systems in rural settings have been taken worldwide, but, the facilities created by such initiatives remain largely underutilized. This is due to a combination of several factors, including understanding cultural background and dynamicity of users, understanding user interface preferences of individual users and technology representation of user interface adaptation. There are challenges in terms of provision and maintenance of ICT infrastructure within different cultural settings, but there are more challenges in terms of computer literacy skills, usability of current applications, cultural constraints and integration of ICT into daily lives of rural users (Wade, 2002; Romm and Taylor, 2001).

Many researchers have tried to identify those factors that can significantly contribute towards increasing the use of ICT in rural settings (Patel et al., 2006; LaRose et al., 2007). However, much work still has to be done to clarify the complexity of accessing impact of ICT in rural settings. This will prepare the ground for rural populations to fully participate in the emerging information society and knowledge economy. There are several on-going research studies that aim to close the digital divide or digital gap that exists between urban and rural settings (Chang et al., 2004; Rao, 2005; Selwyn, 2006). However, such initiatives do not convincingly address the important roles that effective HCI can have on ICT adoption in rural settings (Wong, 2002; Erumban and De Jong, 2006).

One effective way to improve the impact, usability and penetration of ICT in rural settings is to improve the human-computer communication interfaces that are specifically developed to fit the peculiarity of rural users. This offers the means by which the overall satisfaction of rural users can be maximized. In efforts to investigate strategies to improve usability of ICT applications among rural users, HCI for these specific users is examined more closely. A user interface is a system by which users interact with an application. The goal of HCI is to provide a user interface that is easy, efficient, simple and pleasant to operate by a common user in a way that it produces the desired result. This goal has not been achieved mainly because of the diversities of human users. The social-economic differentials between people living in rural settings and those in urban settings necessitate the need to investigate customized applications for rural settings. In particular, the general challenges facing people in rural settings are intermittent power supply, intermittent connectivity, long travel distances, variable population density, limited education, underemployment, limited disposable income and lack of secure storage (Parikh and Lazowska, 2006). These challenges have motivated researchers to look for improved ways to design robust ICT solutions for rural settings (Parikh et al., 2003; Patel et al., 2006; Parik and Lazowska, 2006; Matthee et al., 2007).

There are many more factors impacting on the accessibility of ICT in rural African communities. One such factor is the ICT needs of these communities. Because of the low availability of technological artefacts (Ashok and Beck, 2007), it is difficult for communities to express their ICT needs. User inexperience inhibits their abilities to perceive ICT as a solution to some of the problems they experience. Once they have access to ICT and experience it, they are able to use ICT to solve problems not envisaged at the outset (Matthee, et al., 2007), for example changing crop selection based on information from the internet that was not previously available. Another important factor is how well user interfaces are understood by the people. Rural users are generally less experienced with the use of ICT and therefore, are not confident users. If the user interface uses a metaphor for the graphical user interface, which relies on objects that are unknown to the rural users, such as files, clipboards and more abstract symbols such as inconsistent and variable arrows, the advantages that should have been gained by using a graphical user interface are lost. The unfamiliar objects in the graphical user interface inhibit the intuitive selection of the desired computer action or object.

Although there are many more factors impacting on accessibility of ICT in rural African communities, this study focuses on the user interface metaphors available to rural African communities and examines a method of converting those metaphors into workable user interfaces. In this study, we design and implement HCICI for African users to significantly assist in reducing the digital gap and to prepare rural settings for information society and knowledge economy readiness. In general, readiness of people, business opportunities, available infrastructure and its economy to undertake ICT related activities, intensity of ICT utilization, extent to which ICT related activities are undertaken and impacts of ICT on national economies form important metrics for information society measurements (UNCTAD, 2001). Traditionally, interactions between human users and computer systems are facilitated by a graphical user interface. However, there are many challenges with this approach. Firstly, there is the problem of selecting appropriate metaphors to base the graphical elements of user interface. For example, to rural African users for whom the office metaphor based icons, such as files, clipboards and envelopes are culturally foreign it is difficult to interpret such icon communication.

Secondly, there is the problem of designing appropriate graphical elements based on the selected metaphors, which could be more intuitive for rural African users than the office metaphor.

Thirdly, there is the problem of involving rural African users with low computer literacy skills in the user interface usability tests. These problems can deter wide adoption of applications in the rural settings.

1.1 Rural Information Problems

The advent of innovative mobile devices such as smart phones, PC, tablet and iPad technologies has considerably narrowed the digital divide because individuals can use mobile devices to access information anywhere. Mobile devices are cheap in terms of cost and they are owned by many people, including those in rural seclusion. However, the technology dichotomy among rural and urban communities is currently the challenge of information accessibility, capability and skills of rural users to effectively utilize contents and services provided by innovative technologies. The challenge is no longer much of digital divide, because of the advancement in mobile technologies that can be used to provide contents and services remotely. The contents and services delivered by innovative technology devices have to be easily accessible to be consumable in rural communities. The manner in which contents and services are delivered can potentially be influenced by the nature of user interfaces rendering them. The user interface systems play prominent roles in the engineering of ICT systems and are the means by which users can access the functionalities provided by the ICT systems. The impoverishment of user interface of an ICT system is the bane of the usability of the system.

The people living in the rural communities of most parts of the world have many of the same information needs as those in the urban communities. They are predominantly engaging in small and medium businesses such as farming, fishing, trading, cattle rearing, cloth weaving and brazing works for survival. The rural people need information to connect to those who might be interested in their businesses and to improve their daily productivity. For example, they need current information on fertilizers and how to easily access them at a cheaper price. The rural people also need information about government activities so as to belong to the larger community. They need to be aware of government programs, services and subsidies, some of which may be specifically targeted for their benefit. Rural people need to understand their natural ecosystems to safeguard them for their long-term use and benefit. However, because of the lack of suitable infrastructures, appropriate local contents and sufficient human capacity in rural communities, they often face significant challenges in fulfilling their daily obligations. Moreover, because of the distance barrier, lack of capacity and empowerment, even the most fundamental government services such as registering ownership of a plot of land can prove to be difficult and costly.

Usually, people in the rural communities face the challenge of accessing quality healthcare services. They have to travel long distances to access quality healthcare services at substantial treatment cost. Moreover, the difficulties of managing patient records across clinics and visits make it practically impossible to maintain continuity in the treatment of rural patients. Moreover, rural citizens need quality and affordable education just like people in the urban community. However, unwillingness of qualified teachers to live and work in rural communities has deprived those communities access to quality education, in most cases quality education is a privilege instead of being a right for rural people. In rural communities, the heavy labour demands for agriculture often curtail the educational opportunities available to rural children.

There is a general consensus worldwide, which given the recent reductions in the cost of technologies, appropriate introduction of computing and related advancement in ICT can help to address many of the information quandaries often experienced in rural communities. Learning about new business opportunities, innovations and obtaining timely information from markets can help to improve the livelihoods of rural producers. However, rural areas in the developing parts of the world often pose a number of distinctive challenges for the technologies being deployed to those communities. Many of the information challenges are well documented in the literature and can be classified into environmental and individual user challenges (Chetty et al., 2004; Parikh and Lazowski, 2006).

1.1.1 Environmental Challenges

The environmental challenges of information access include such things as intermittent power supply because the power grids in developing nations are notoriously unpredictable. A battery-powered Uninterruptible Power Supply (UPS) technology is what people from most parts of developing nations rely upon. The intermittent connectivity is another bottleneck because connectivity is spatially intermittent. High quality copper wire landlines are prohibitively expensive to extend to rural communities with a limited revenue base. Long travel distances and unaffordable time wastage is difficult for rural people. The quality of roads is often poor and increasing driving times are burdensome. Public transportation systems rely on several transfers to travel from one place to another, so travelling is incredibly time consuming. There is a lack of secure storage facilities in rural communities and cases of theft and damage frequently occur when innovative technologies are installed.

1.1.2 Individual User Challenges

The individual user challenges are those issues that have to do with the inability of users to engage meaningfully with ICT systems. These can be because of their low level of skills and educational background. The challenges of people residing in rural communities often create limited access to education for people. The low quality of schools in rural communities and intensive demands for agricultural work often force children to abandon schooling at an early age. The majority of those who struggle to succeed in attaining a high school education often seek employment in the urban communities where salaries are considerable higher and condition of services are considerably better. Large numbers of people living in rural communities are considered illiterate, so human capacity is a challenge in these communities. The lack of economic opportunity in rural communities, combined with the inconsistent performance of farming, create acute cases of underemployment. Many persons living in rural areas live below the poverty datum line. Severely curtailed disposable incomes are an endemic problem.

1.2 Research Questions

The HCI designers of ICT systems are frequently faced with the problem of how to accommodate human user diversities to facilitate good user interface design. Human users differ in several ways, including differing culture, skills, education, experience and diversity in their requirements for using application systems. The development of an application system to deal with diversities in user cultural background, user ways of working and individual personal differences of a user is therefore a difficult problem. The general solution proposed in the literature is to build an adaptive capability into application systems or their user interfaces, which can then adjust the functionalities of the interface to suit an individual user (Benyon and Murray, 1988; Heimgärtner, et al., 2008).

The design of user interfaces has so far been done without the participation of African users. This has resulted in non-user-centric interfaces that without extensive training are hardly usable for the vast majority of rural African users. This design approach contrasts the Millennium Development Goals (UN, 2006). The problem that needs to be solved therefore is how to design user interfaces to increase application usability for rural African users. The investigation consists of a pilot study (Heukelman, 2006) that identified one of the user interface problems as comprehension of icons based on the office metaphor among rural African users. The metaphor approach is rapidly gaining popularity among researchers from academia and industry as a coherent framework to integrate user interaction and information presentation (Barr et al., 2005; Hofmeester and Wixon, 2010; Yang, et al., 2010). However, the challenge lies in identifying a suitable metaphor to base a graphical user interface on that could improve usability for rural users. The metaphor must link objects familiar to rural users to computer objects and actions to facilitate HCI between rural users and computer applications.

A design method to translate a metaphor into suitable graphical components for a computer interface for rural users is needed. Different icons design methods are normally used and the resulting icons are tested for usability (Sharp et al., 2006; Payne and Starren, 2006). The contribution of African users in determining the intuitive understanding of interface object metaphors and related computer actions must inform the design process (Evers et al., 1999; Duncker, 2002). The support of African based computer interfaces as opposed to the common vendor office based computer interfaces must be empirically determined. In addition, the contribution towards a better understanding of ICT system usability issues for rural users should be empirically determined. If there is an underlying resistance to an alternative user interface, even if understanding is improved, it should be identified. As a result, the first research question that was answered by this study is stated as follows:

a) What are the factors that will likely influence the support of African rural users for alternative village object metaphors as interface icons?

In HCI research, culture is a factor that is generally believed to influence interactions between users and ICT systems because users act within a cultural milieu (Röse et al., 2001). However, there is the necessity to empirically test the effects of culture on user support for alternative concrete interface objects. Consequently, the second research question of this study is stated as follows:

b) What effects will culture have on the support of African rural users for alternative African village object metaphors as user interface icons?

If Africa rural users express support for alternate concrete African village object metaphors, then it becomes natural for system designers to implement cultural objects adaptively in application systems that specifically target African rural users. Consequently, an important issue that should be resolved by researchers is how to detect specific response characteristics that differ among diverse system users. As a result, it is important to empirically determine response characteristics that differ among diverse groups of system users. In this regard, the third research question of this study is enunciated as follows:

c) What response characteristics will differ among African rural users in their support for alternative interface metaphors?

1.3 Study Rationale

The improvement of user interface usability specifically for African users could contribute towards improving a number of opportunities for rural users. These opportunities include easy access to better education, economic opportunities, medical information, online government services and better communication. In general, this study contributes towards bridging the digital divide, improving accessibility to sevices and promoting the use of ICT in rural communities. A significant number of people worldwide live in rural settings and their effective participation in the information age is being hampered by lack of easy accessibility to ICT. In this context, it is important to emphasise that availability does not imply accessibility, which can be hampered by usability problems. Consequently, an ICT system can be available, but because it is not usable it is not accessible.

The relevance of this study lies in assisting ICT system designers to understand usability issues before creating ICT solutions. ICT systems usability will encourage rural communities to use ICT facilities, become more ICT literate and exploit ICT to increase their socio-economic participation. The general support for cellular telephones demonstrated by rural communities, shows that those communities are ready for electronic communication. The social benefits to be gained by rural communities include greater access to information, including educational programmes, a broadening of economic markets and better service delivery by government. Distance education may now become more accessible, with all the associated benefits. The economic benefits include possible growth by small enterprises in the rural areas, which in turn will contribute to creating more employment opportunities. The higher levels of computer literacy will encourage greater e-participation and e-commerce, which contribute to the economy in general.

The political benefits of this study include access to government services and information provided through the Internet. A study was done to determine how ready communities are to accept online service delivery through websites (Averweg, et al., 2003). The result of this study shows that greater ICT penetration in rural areas could result in better service delivery and could greatly benefit rural communities. The main focus of our study is contributing to the development of better computer user interfaces that can allow people with low computer literacy levels to interact better with the technology. This has the potential to increase the use of ICT in rural areas to support diverse social-economic activities. This study, therefore contributes towards ICT in general by creating a better understanding of the process of designing computer user interfaces for rural communities by their involvement in the design process. The evaluation of user interfaces by the intended users would lead to more suitable user interfaces enhancing the whole process of HCI design.

1.4 Design Strategy

This study was conducted using a participatory ICT system design approach based on bodystorming (discussed in Chapter 3) and cultural probes to establish the support of African rural users for alternative African village metaphors. The purpose was to determine whether alternative African village metaphors could intuitively be linked to computer actions and whether they can be supported for interface icons as opposed to office icon metaphors. A group of African small enterprise owners were selected from the rural community of Umbumbulu on the South Coast of KwaZuluNatal province in South Africa to participate in this study. A pilot study was conducted to identify usability problems with current general use applications for African rural users (Heukelman, 2006). A computer training program, comprising of the use of office software productivity enhancement packages such a word processor, spreadsheet and presentations was organized for rural participants to cater for the shortage of skills problem. This was followed by training on an open source accounting package, which was translated into the language of the participants. Cultural probes and bodystorming within the rural context were used to gain a better and richer insight into the environment of the rural participants and to identify usability problems.

This study develops the Technology Support Model (TSM) based on the human cognitive properties of knowledge, comprehension, skills and performance to explain African rural users support for alternative concrete metaphors. The empirical data that was generated was analysed using the Partial Least Square (PLS) analytic modelling method to establish hypothesized relationships between constructs of TSM. This was also to examine the influence of culture on user support for alternative African village metaphors as interface icons. The Finite Mixture-PLS (FIMIX-PLS) segmentation algorithm was used to study the heterogeneity in the empirical data.

The research design strategy for the empirical experimentation of the support of African rural users for alternative concrete metaphors consists of three main parts:

a) The knowledge of African rural users concerning the current office based user interface icons was assessed by an instrument that was developed in this study.

b) The support of African rural users for alternative village object metaphors was determined for the creation of icons representing computer actions and evaluated in terms of recognisability.

c) The objects from the African village metaphors were evaluated in terms of the support of African rural users for alternative metaphors and the ability of rural to intuitively associate these icons with computer actions.

1.5 Summary of Contributions

The main contribution of this study lies in the development of a Technology Support Model (TSM), which is a new model to empirically establish user support for a technology. The model was validated to establish the culture interaction effects on relationships between independent constructs of knowledge, comprehension, skills and support. In comparison to the existing technology adoption models, the TSM is unique for the following reasons. The majority of existing adoption models is well suited to explain or predict user intention to adopt a technology. Moreover, they utilize the characteristics of technology such as perceived ease of use, perceived usefulness and technology-task fits to explain or predict user intention to adopt technology. The challenges of these extant adoption models are that characteristics of technology cannot sufficiently allow user behaviour to technology to be fully understood. In addition, information system researchers have agreed that intention is different from behaviour and there remains a gap between intention and behaviour. Lastly, these technology adoption models were mainly developed for pre-adoption regime, but not well developed for post adoption regime.

The TSM developed in this study takes a different approach to technology adoption and utilizes human characteristics such as knowledge, comprehension and skills to apply technology. These human characteristics are then explored to establish human support for a technology. Adoption is synonymous to acceptance and use of technology, but support goes beyond adoption. Technology support encompasses adoption, technology promotion, technology development, technology advocacy and so on. Moreover, this TSM is well suited for both pre and post adoption regimes and can be applied to individuals to determine their support for a particular technology. Specifically, the contributions of this study to the HCI body of knowledge are summarized as follows:

a) The development of a participatory framework based on bodystorming and cultural probes to examine the support of African rural users for alternative African village metaphors as interface icons.
b) The development of a TSM based on human cognitive properties instead of technology characteristics that can be used to establish support for ICT systems.
c) The empirical establishment of the effects that cultural diversities can have on human support for ICT systems.
d) The empirical identification of human cognitive characteristics that affect human support for ICT systems.
e) The empirical study of heterogeneity detection in HCI empirical data generated from African rural users participatory experience.

1.6 Synopsis of the Thesis

The remainder of this thesis is for the sake of easy readability succinctly summarised as follows. In Chapter 2, the state of the art related research works on improving ICT access and user interface usability in rural areas worldwide is highlighted. The obstacles to good utilisation of ICT are examined and a user centred approach to designing user interfaces, thereby designing for specific users are investigated. In Chapter 3, the preliminary study that was conducted on user interface is reported. The preliminary study engaged African rural users to establish the interface icons that present problems. In Chapter, 4 an empirical study on user interface usability is reported. A set of 14 research hypotheses, which were constructed from the research model are discussed. In Chapter 5, the data analysis method that was used to establish relationships between constructs of the research model is discussed. In Chapter 6, experimental results of the relationship analysis and the discussion of these results are presented. Finally, in Chapter 7, the summary of the results of the thesis, further work and conclusion drawn are discussed.

Chapter 2 Related Studies

The use of ICT for all populations, regardless of their culture, language, education, religion and demography has been strived for by many governments across the world. Many researchers have grappled with the problem of introducing ICT to a diverse range of people in terms of education, literacy and economy (Patel et al., 2006; LaRose et al., 2007). As a result, improving ICT accessibility has been targeted by many different interest groups. The United Nations Millennium Goal 8 (UNMG8) states that a) develop a global partnership for development and b) in cooperation with the private sector, make available the benefits of new technologies, especially ICT resources such as telephone lines and cellular subscribers per 100 population, personal computers in use per 100 population and internet users per 100 population (UN, 2006). This means that the measure of how well the target populations and the goals that have been achieved are the number of personal computers per 100 of the population and the number of internet users per 100 of the population, indicating the penetration rate. There is therefore a huge drive worldwide to try and achieve the Millennium Development Goal by increasing penetration rate of the use of ICT to the social and economic benefit of all individuals. In this chapter, an overview of relevant studies is presented to identify current trends.

2.1 Rural User Participation in ICT Studies

There are many initiatives to develop specific ICT infrastructures and systems targeting rural settings. For example, Parikh et al. (2003) report on a Financial Management System (FMS) designed for micro-credit groups in rural India. In another study involving rural community researchers in the Eastern Cape of South Africa, an initial prototype telemedicine system was developed for rural South African communities (Chetty et al., 2004). In a case study by Pade et al. (2006) the categories associated with ICT project sustainability in rural areas were investigated. Ramachandran et al. (2007) researched the social dynamics of early stage co-design in developing regions. Matthee et al. (2007) followed a collaborative approach to provide internet connectivity in Macha, Zambia to improve the quality of healthcare in the region. These examples of ICT infrastructure for rural community development exhibit some differences, but also many similarities. A common factor that surfaces in some of these rural ICT studies is the participatory design approach. The villagers in rural communities were participants in the study conducted by Parikh et al. (2003). The researchers conducted field trips to discuss a paper prototype with villagers operating a micro-credit system, which consists of writing up details by hand. Group meetings in different locations were held and information about the existing hand-based system was gathered. The villagers, who are essentially not computer literate, at a later stage, evaluated an interactive prototype based on a standard screen resolution on a laptop, contributing towards improving the design (Parikh et al., 2003). However, the details of the actual evaluation process and criteria were not described.

Community members also participated in the study conducted by Chetty et al. (2004). The researchers followed a cyclic, iterative and participatory approach. The study used discussion groups, semi-structured interviews and consultation by cellular phones to involve the target community members in the development of a new telemedicine tool. The design team also conducted field visits to rural users who were predominantly literate and have had some experiences with online consultation. The study by Ramachandran et al. (2007) also engaged the participation of community members. The researchers conducted three field studies in different locations. Participants were exposed to technology and then interviewed about its use and in some cases a survey was completed. The authors use the term early stage co-design to refer to the steps through which designers understand current tasks, needs and practices of potential users, usually through processes like needs assessment, task analysis, contextual inquiry, or other methods that fall under the umbrella of formative design and evaluation in HCI. Participants were therefore involved in helping the designers to understand the needs and context of use of ICT and participated in evaluating the usability of the technology that they were presented. Matthee et al. (2007) involved different organisations from different parts of the world to participate in designing solutions to the technical problems associated with rural internet connectivity and funding. They presented three case studies where internet connectivity had direct social benefits to the community. The rural community therefore identified the needs and requirements, participating in the solutions design by ensuring that their needs and requirements are identified, which the multidisciplinary team proceeded to address. Once the initial needs were met, other benefits also became apparent and participants could use the technology to initiate a number of new projects.

In all the above studies, rural participants were mainly involved at the design phase. Prototype systems were evaluated by participants, designers incorporated comments and improved the design and participants evaluated the design again.

2.2 Rural System Participatory Design

The question of what rural settings have to gain in a participatory design becomes apparent. Besides the members, who else can gain from it and what can be gained from it? Can such evaluations add value to the HCI knowledge base? Can these interventions lead to new HCI paradigms? In an attempt to provide answers to these important questions, community informatics has emerged. The notion of community informatics is defined as the application of Information and Communications Technologies (ICTs) to enable communities overcome "digital divides" and “service accessibility divides” (Centre for Community Informatics, Research, Development and Training, 2006). In this section an overview of previous studies in community informatics that have attempted addressing these important questions is presented.

In a paper by Stoecker (2005), based on a literature study, some of the questions confronting the emerging field of community informatics are raised. Critical among these questions is whether community informatics serves elites, academics, community workers or the community? Stoecker (2005) points out that the design of technology is driven by the demands of the rich for profit, but not by the demands of the poor for access (Stoecker, 2005). Consequently he suggested the development of an empowerment model for community informatics emphasizing a community development approach combined with information that is focused on a participatory process. This would mean that participation occurs in a community development context as people study their own community and began to identify local community issues. People would identify a set of information they need to manage to support specific community development projects (Stoecker, 2005). Furthermore, Stoecker (2005) argues that by identifying local issues and developing solutions to meet the needs of the community. The community is empowered to solve their own problems and enhance their living. Even though Stoecker (2005) makes a strong case for community participation in system development, it is unfortunate that he does not provide empirical evidence for his case. As a result, the impact of community participation in ICT system development could not be evaluated.

The study by Tedre et al. (2006) is similar to that of Stoecker (2005) in the sense that they investigated the social and cultural context of ICT. They argue that ICT is not a value per se, but only becomes a value when it responds to the needs of a particular group (Tedre et al., 2006). These authors further argue that the needs of a rural community are vastly different from a highly industrialised urban group for which most software applications are developed. As a result, they propose an approach that recognizes the relationship between science, society and technological development. They presented the viewpoint that society shapes ICT development and proposed taxonomy for understanding local computational concepts. They raised the question of whether computer science would benefit from taking local knowledge into account (Tedre et al. 2006). They concluded that this new perspective should benefit computer science in the form of different points of view on old concepts or even offering novel concepts (Tedre et al. 2006). There are indications that computer science as a discipline could be enriched by the knowledge gained when computer software is evaluated by rural users.

Ashok and Beck (2007) propose that current HCI theories and methodologies that were used in urban settings may not be suitable for the rural settings. The authors claim that the nature of villages being devoid of digital artefacts requires much of HCI theories and methodologies to be re-examined. The researchers maintain that common problems faced in past interventions in developing countries result from self-centred focuses on the developers rather than those who are affected. The solution proposed by Ashok and Beck (2007) is to include activity theory in the HCI design paradigm. They examine a number of case studies described in the literature to support their inclusion of activity theory. The inclusion of activity theory into current HCI theories and methodologies could contribute towards broadening the base of HCI knowledge and towards the field in general.

The contribution to be made by non-mainstream rural evaluation of software systems is supported by a study on motion-impaired users (Keates et al. 2000). In the study the applicability of user models for motion-impaired users was investigated. A set of trials with heterogeneous users across the different disability types was established to validate the user model in terms of the theoretical basis. The users were specifically chosen to represent a broad range of impairments and severities to avoid condition-specific or impairment-specific results (Keates et al. 2000). The results of the first trial showed that certain types of motor function did not follow the theoretical model, but they were not conclusive and a second set of user trials was conducted. The results of the second study showed that individual components of a Model Human Processor (MHP) model are comparable for able-bodied and motion-impaired users (Keates et al. 2000). The implication for those relying on models of interaction for designing interfaces or usability tests is not to rely on the accepted able-bodied models and 'add a bit', but to actually measure the difference in the interaction styles between users with different capabilities (Keates et al. 2000). Studies such as these contribute significantly towards the body of knowledge of computer science as they challenge existing models to include a wider range of users.

One of the important conclusions drawn from the study by Ramachandran et al. (2007) is that unique social network structures embedded within communities are crucial to the acceptance and potential adoption of technology. Local stakeholders can contribute cultural information relevant to the design as needs and practices through interaction with technology artefacts. This supports the use of local activities to inform the design process as proposed by Ashok and Beck (2007), which in turn enriched current HCI theories and methodologies.

In a paper by Gregor et al. (2002) an approach to design systems for dynamic diversity is presented. Although the case is argued for older people, the aspects that receive attention are vision diversity and diversity in older adults, including memory diversity, confidence levels and interface support (Gregor et al., 2002). The paper examines those results from experiments that were reported by other researchers to identify characteristics of older people. The authors use the characteristics identified to review the user-centric system design methodology and suggest a methodology they call User Sensitive Inclusive Design (USID) (Gregor et al., 2002). The contribution made by a community is to enrich the design process and thereby contribute towards knowledge within the field.

Rural communities also stand to gain from becoming involved with the development of ICT initiatives within their communities. Research by Patel et al. (2006) involved the creation and deployment of iShakti, a virtual information and marketing channel in 1000 rural kiosks in India, covering 5000 villages and reaching 1 million people. Through the iShakti entrepreneur program Hindustan Lever Limited (HLL) creates livelihood opportunities for underprivileged women. The initiative offers participants a platform to sell goods, but also offers information on inter alia health, beauty and legal aspects. By relying heavily on audio-visual content, designers have increased accessibility for users with low literacy skills and no experience in the use of computers. Audio feedback formed the corner stone of making the software more accessible to users with low literacy and computer literacy skills.

The case study by Mathee et al. (2007) on a collaborative approach to bringing internet connectivity to rural Zambia is a proof-of-concept that there are social benefits, which were not foreseen. The initial project was undertaken to improve access to medical information, while the unforeseen benefits included diversification of crops and data capturing contracts. Parikh et al. (2003) analysed his experiences in establishing relationships with the villagers in Guatamala for whom the CAM: A Mobile Interaction Framework for Digitizing Paper Processes (MIFDPP) in the developing world, based on the CAM recorders for micro-finance systems in rural India were developed. Parikh et al. (2003) listed a set of practices that were used to establish a relationship with village participants, but conclude that they have been afforded this opportunity in the expectation of mutual benefit. The literature therefore suggests that both rural communities and computer science as a discipline could benefit from involving the rural community in the design and evaluation of computer software. From the literature, it is apparent that both HCI theories and rural communities have much to gain in participating in the design of adaptive user interfaces.

2.3 Rural System Usability Evaluation

The important issues to discuss in this section are the following. Why is the location where system design and assessment takes place important? What are the possible locations for software design and evaluation by a rural community? The possible places where the usability evaluation of software could take place include usability laboratories (Andreasen et al., 2007), the workplace where the software is intended to be used (Rose et al., 1995), at telecentres in rural settings (Pade et al., 2006), informal locations such as the village gathering place in the open (Parikh et al., 2003), some private house (Ramachandran et al., 2007) and in a community hall (Parikh et al., 2003). Rose et al. (1995) developed a framework based on ethnographic methods for observing software users in the workplace and for the redesign of user interfaces. These authors asserted that participant observation within the workplace using the framework they developed led to the users becoming increasingly active in the evaluation of their new system. Ethnographic methods, which are based on principles of participatory design have proven to be an effective tool in user interface evaluation (Rose et al., 1995). This is further supported by a study by McDonald et al. (2006) that ethnographic techniques provide rich and far-reaching data that capture problems originating within and outside the system.

A study by Parikh et al. (2003) to evaluate a Financial Management System (FMS) for micro-credit groups in rural India engaged a set of rural women in system evaluation. The study concluded that staying in the local area and doing design work in the field was a very important part of their design process. Ramachandran et al. (2007) investigated the social dynamics of early stage co-design in developing regions. The findings were based on three field studies in Tamil Nadu, Uganda and Uttar Pradesh. In the studies in Tamil Nadu of India, interactive sessions were conducted on the porch outside the doctor's office, inside the house and in the front yard. Researchers observed and interviewed stakeholders on how they interacted with semi-functional prototypes of a voicemail and point-of-sales handheld device respectively to elicit feedbacks that informed new design directions. The researchers in Tamil Nadu conducted 37 sessions in uncontrolled settings at the village over four days. The participants were not selected based on predefined criteria, but sessions were conducted in informal settings, for example on the porch, outside in the yard, inside a private house and under the street lights.

In Uganda the researchers participated as third-party evaluators in the Remote Transaction System (RTS) pilot for 3 weeks. The researchers observed group meetings of clients and interviewed five clients from each group. The locations of the meetings were not explicitly described other than that although cellular coverage was expected, but there was no coverage at both meeting locations. Approximately 90% of the Ugandan population live in low density rural areas (Ramachandran et al., 2007), which suggests a rural setting. In Uttar Pradesh of India, children were given digital cameras to photograph subjects that they valued and considered important to their lives outside school (Ramachandran et al., 2007). The digital camera system evaluation took a different form as children identified the limitations regarding the use of digital cameras after their return (Ramachandran et al., 2007). The limitations could be identified by researchers looking at the photographs that were taken while each of the children had the camera. Although the device was used in the field, the evaluation was done in locations of the researchers' choice.

Initial evaluations to gain local insights may be in more informal settings. During another trial trip to develop the micro-credit system, researchers conducted evaluations in a more controlled environment (Parikh et al., 2003). Based upon the studies of Parikh et al. (2003) and Ramachandran et al. (2007), researchers had to change their locations for software evaluation to rural communities. This gives an indication that within the rural context, the location selected for the evaluation of the software can be anywhere (a private house, outside under street lamps, or at the local telecentre if there is one) depending on the evaluation stage. The location of the evaluation of the software as described in the literature should therefore be adapted to suit the current situation, the stage of the assessment and the availability of facilities. Researchers and designers in rural areas gain the opportunity to familiarise themselves not only with the context of use, but also with the wider environment within which rural communities live, including utensils and tools used in their everyday living.

2.4 Interface Evaluation Criteria

The following questions are raised in the literature as aspects that should be addressed by software usability evaluation. Do the applications and actions closely match the reality of the actions normally executed to achieve tasks (Romm and Taylor, 2001)? Can rural communities with English as second language and sometimes third language understand and fluently communicate with user interfaces where English, Western style metaphors and technical jargon are dominant (Cuncliffe et al., 2005; Blake and Tucker, 2006)? Are the icons meaningful within the rural culture (Evers et al., 1999; Ferreira et al., 2006; Lindberg et al., 2006; Wang, 2007)? System sustainability is another important aspect to be evaluated (Pade et al., 2006). As a result, several evaluation criteria need to be considered when conducting user interface evaluation. These criteria include rural lifestyle, language, icon recognition and culture.

2.4.1 Rural Lifestyle

The assessment should firstly include whether within the rural context, the application could enhance everyday living and tasks (Romm and Taylor, 2001). These authors analysed the emerging literature on community informatics as a backdrop for a model that can explain and predict the prospects of community informatics projects. They identified integration as an important factor to integrate the system into the routine life of a community, local content for local needs, linkage to local government, schools and social services and processes that ascertain long term sustainability. Under local content, the appearance of a user interface and information of local interest could be understood. In a summary document by Singh and Shinde (2004) one of the challenges of achieving ICT penetration and access in rural areas and of subsequent utilisation is identified as content that is irrelevant to the livelihood priorities of poor communities (Singh and Shinde, 2004).

In a paper by Ashok and Beck (2007), which examines case studies of rural ICT interventions, two case studies are compared. The benefits of a study where researchers placed a computer connected to the Internet in slums and villages of India were mostly unrealized (Ashok and Beck, 2007). However, another study where researchers provided kiosks, which provide market prices and better agricultural practices to Indian farmers, enabling them to procure better rates for their produce and use better farming methods, fitted seamlessly into their daily activity and realised its full potential. In both studies computers with internet access were provided, but in the one case it was an add-on to the daily activities, while in the other the internet fitted into the daily activities by addressing a specific need. This paper supports the concept that computer applications must improve existing daily activities within the rural communities. Patel et al. (2006) report a “high usage: 9.5 hours daily at 98% capacity” for the use of iShakti, a real-world Intelligent Interactive and Adaptive Web (IIAW) application, deployed across 1000 rural kiosks in India. A pilot study involving 8 villages, 4 test villages and 4 control villages reported positive feedback on the value of the information provided and responses by experts to posed questions. A focus group discussion within the village was used to identify the needs of the people. In addition, “iShakti was constructed to offer information services to the people, thereby meeting the totality of the needs of people across demographic sectors and providing a rationale for everyone in a small village to make use of iShakti”. The project provides the needs as expressed by the villagers and improves their daily lives.

The ISO 9241-11 defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a special context of use” (Jokela et al. 2006). This means that rural communities must be able to use the software within their context of use to achieve their goals and must therefore assess whether the software allows them to achieve their goals within the rural context. In the key principles of user-centric design as described on the website of usabilitynet.org, the designer must bear in mind the characteristics of the user population, their real-world tasks and their working environment (Usability.Net, 2002). This emphasises that the software must be of use to the user population in solving their real world problems, so rural communities must assess whether the designer has developed a product that they can use to solve the problems within the rural context. How well the application matches the way in which the familiar tasks within the rural community are resolved and whether it fits in with everyday life is an aspect to be evaluated.

2.4.2 Language

Existing literature also reveals that language is another aspect to be evaluated. Cuncliffe and Roberts-Young (2005) studied existing websites to "examine the extent to which the Welsh language is being presented as a usable tool through which individuals may be informed about and participate in civil society in Wales". The research compared websites with a link to a second language on bilingual websites. One of the findings was that the website should be developed in the language of the intended user group, which indicates that translated websites are not necessarily as successful as it is hoped. User populations should therefore evaluate the software to determine whether the language used is understandable.

The ability of a community to communicate with the application must therefore be evaluated. Blake and Tucker (2006) are "developing a community-centered approach to learn how interaction techniques can compensate for poor communication across the digital divide". They are developing a computer based tool of which SoftBridge is the basic building block that act as an automatic communication bridge between various groups. "One application is to bridge communications between disadvantaged deaf users by translating from text to speech and back again" and "another is to provide access to professional medical information for nurses in remote rural clinics in the face of frequent power and other infrastructure outages" (Blake and Tucker, 2006).

Patel et al. (2006) recognized "low literacy skills and no experience in the use of computers" in rural villages in India in their design of iShakti. "employing user-centered design principles, iShakti has been developed with heavy emphasis on audio-visual content" and the system has "an audio file which 'reads out' the content to the end-user". Communication with the system has therefore been adapted to the needs of the users.

2.4.3 Icon Recognition

A number of studies on the recognition of icons, both on computer and on cellular telephones have been done. Evers et al. (1999) hypothesised that expectance of which information would be behind an icon would depend partly on the user's understanding of the icon. Wang (2007) explored the relationship between English proficiency and computer experience among Taiwanese computer users and their ability to identify icons. Ferreira et al. (2006) designed an Icon Intuitiveness Test (IIT) to gain better insight into how users interpret icons. Lindberg et al. (2006) investigated how age affects the speed of perception of computer icons. In another study by Kim and Lee (2005) icon recognition in mobile phone interfaces by different cultures, according to level of abstraction was investigated. Hoggan and Brewster (2007) designed and tested audio and tactile cross modal icons for mobile phones.

Evers et al. (1999) investigated cultural aspects of understanding the website of a virtual campus. Users from English, Dutch, Sri-Lankan and Japanese backgrounds completed a task/question list and were interviewed on using a website to provide information on a virtual campus. The website informs people about distance learning courses and is used to communicate with students. The results from this study suggested that labels can have different connotations for different cultures reflecting the linguistic origins. The function and role of metaphors is not necessarily at fault, but more the fact that users do not have the right concepts to make the mapping back to the real world (Evers et al., 1999).

The finding that users should have a certain level of experience to link the icon to the right action is supported by Wang (2007). The study by Wang (2007), which explored the relationship between English proficiency and computer experience in the identification of icons identified 20 standard icons to be identified by eight groups of participants with different levels of English proficiency and different levels of computer experience. The results of the study showed that “a participant’s familiarity with using computers was more important than his/her English ability in identifying the icons shown in the tests” (Wang, 2007).

Ferreira et al. (2006) grouped 20 icons that would not be too familiar to experienced computer users. Some icons selected had different representations, but had the same underlying functionality. These icons were chosen so that one representation was an iconic sign and the other a symbolic sign (Ferreira et al., 2006). The icons were chosen from word processing and spreadsheet software, Maths/Statistics software and telecommunications software. A paper based questionnaire with the icons grouped according to the context from which they came was presented to participants. This study also found that their experience with computer applications affected how easily they could guess the correct functionality of the icon (Ferreira et al., 2006). The study found no significant difference in the recognition rate of iconic and symbolic signs.

The aim of the research by Lindberg et al. (2006) was to determine whether age has an effect on the performance in icon search and whether the possible age effect has any interaction with icon size or spacing. All the participants had experience with using computers and were familiar with the concept of computer icons. "In the experiment the subjects were asked to find a target icon from a set of distracters. The target was either present or absent, both with a probability of 0.5" and depending on whether the icon is present or not, participants were to click a button with the picture of the icon or a button labelled "no". The study showed that "people with subnormal vision are likely to experience difficulty with small icons and icons that are far apart", but by using icons with a moderate size and spaced fairly close together, these participants could perform on the same level as people with normal vision. The study found no evidence of age affecting the higher-level processes of visual perception.

Kim and Lee (2005) gathered menu icons, which were used in mobile phones in Korea and America and classified them depending on their metaphors and how well they represented the icon referents (actions). "Icons representing five referents (Call log, Message, Downloads, Voice Recording and Web) were ranged" from abstract icons, semi-abstract to concrete ones (Kim and Lee, 2005). Web-based interactive questionnaires were used to determine recognition and preference. The study reported that "cultural difference was found to some extent in icon recognition according to the level of abstraction" but the difference was not significant enough to prove a difference in icon recognition between Koreans and Americans.

Hoggan and Brewster (2007) investigated how well cross-modal icons are recognised by users, where audio and vibrations are used to identify messages from different sources. Three pieces of information was encoded in each alert: the type of message (rhythm), the urgency of the message (roughness) and the sender (spatial location). The message could be text, email or voicemail. The urgency could be urgent or not urgent and the sender could be work, personal or junk. Participants were asked to classify the incoming messages. The results suggest that roughness parameter is not as effective as rhythm and spatial location, but that cross-modal icons could be effective in mobile displays.

In summary, experiences of users influence their abilities to relate an icon to the action it represents more than their language or culture. Users are able to identify cross-modal icons, which give more information and age does not have an effect on the higher-level processes of visual perception resulting in older users still being able to relate the icon with the relevant action.

2.4.4 Culture

The influences of culture on interactions between ICT systems and end users have been studied in HCI research (Hofstede, 1991, Röse et al., 2001, Heimgärtner, 2006, Heimgärtner, 2007). The concept of culture captures the values, beliefs and behaviours of a group of people, which can be a nation, a region or a team (Heimgärtner et al., 2008). The primary need to model cultural dimensions is to describe the behaviour of the members of different cultures and support quantitative analyses of the characteristics of different groups (Hofstede, 1991). In the case of HCI, cultural dimensions are directly related to communication, information, interaction and dialog design and concern the culturally differentiated concepts of space and communications (Heimgärtner et al., 2008). Many researchers have demonstrated that the solution for improving user satisfaction of ICT system is by considering culture in user interface design (Sheppard and Scholtz, 1999; Ford and Gelderblom, 2003). Culture does influence user perception and preferences of ICT systems and the way people perceived the world.

In exploring the relationship between individual and cultural factors for interactive system design, several research studies have been done on cultural adaptive user interfaces. There is a keen interest among researchers to model the individual requirements of users relative to cultural factors. This has led to the development of different methods to support design sessions in the real context of the users. Examples of these methods are cultural probes (Gaver et al., 1999) and bodystorming (Oulasvirta et al., 2003). Asokan and Cagan (2005) employ a design tool to create a balance between cultural and technological factors to support meaningful innovations embedded in the roots of cultures. Iqbal et al. (2005) investigated the cultural requirements for the design of new ubiquitous collaborating systems. In their study, they extended ethnographic methods to develop the ethno-model that combines ethnographic with Unified Modelling Language (UML) models to provide rich and concrete portrayals of the user context. The study by Duncker (2002) provides an evaluation of cultural influences that imply some system design metaphors are appropriate for some cultures and inappropriate for other cultures. The author studied the library metaphors of digital libraries in the cultural context of the Maori of New Zealand and discovered that cultural factors influence the development of metaphors.

2.5 Evaluation Method

The concept of system evaluation is well promoted in system analysis and human-computer interaction. Among the developers of interactive systems and users of such systems, there is agreement that usability is an essential quality of software systems. The usability evaluation methods were introduced to assess and improve usability in such systems. This has led to a variety of alternative approaches and methods to test systems, products and somebody to test the systems or products. User interface evaluation or usability testing methods employ a number of different strategies. Hom (2003) broadly groups evaluation methods into three main groups, namely inspection, testing and inquiry. The methods categorized as inquiry include contextual inquiry, ethnographic study, field observation, interviews and focus groups, surveys and questionnaires (Rose et al., 1995). In these evaluation methods the emphasis is on users evaluating the interface within the intended context of use. This means users from the intended target group participate in the evaluation of the product within the context where it will be used.

2.5.1 Data Gathering

Data gathering for the purpose of evaluation could pose problems due to the intended technological inexperience of users. In a study on the development of information technology related products for older people, it was stated that "eliciting requirements from older people who often have limited experiences of ICT poses unique problems" (Eisma et al., 2004). Older people have very diverse capabilities. There is great variability in terms of physical fitness, cognition, experience and environments. "User Centric Design (UCD) methodologies have been designed for user groups with relatively homogeneous characteristics. 'Older people' encompass an incredibly diverse group of users, according to Gregor et al. (2002). Eisma et al. (2004) focussed on "the methods of interacting with and obtaining high quality data from older people. The cultural and experiential gap between researchers and older people can be especially large when developing information technology products" (Eisma et al., 2004). The study used a variety of communication methods such as questionnaires, focus groups and interviews (Eisma et al., 2004). It was found that respondents were not as confident to answer positively or negatively and often used the "I don't know" option. However, this improved if the questionnaire was administered by a researcher.

In the study by Ramachandran et al. (2007), a new technology was introduced to participants in the Tamil Nadu, India field study by way of a "hands-on demo exercise and participants could repeat the same tasks until they wished to stop". Participants were interviewed using interpreters on their experience and their other thoughts and suggestions about the technology. The same pattern was followed in Uganda, where the technology was introduced by way of a training session, followed by interviews. The third field study, in Uttar Pradesh, India by this group of researchers also introduced the participants in general to the technology, after which prior to each child taking a camera home "he/she was personally trained on the camera and tested to ensure that he/she understood its operation completely. The following day the child was given the chance to share the photographs with an interviewer, interpreter and observer. The photographs facilitated the interviews and were used to ask detailed questions about the people and practices pictured". Unfortunately, in none of the above evaluations was detailed information given about how the technology performed. The focus of the evaluation was on whether a participant could use the technology and not how well he/she could use it.

Research by Parikh et al. (2003) presented paper prototypes in Aurangabad, India as the basis for discussion by villagers and researchers could gauge their understanding of "the numeric keypad and its purpose as well as most of the icons included in the interface". This field trip was followed by a trip to Madurai, India where "an interactive prototype based on a standard screen resolution" on a laptop was used to give more flexibility in the evaluation of design alternatives. Participants could give feedbacks on aspects such as how well the prototype matched the real life system and colour, while researchers could observe their use of the touchpad. On a third filed trip, back to Madurai, a more advanced prototype was used. Researchers aimed to use numeric shortcuts for faster navigation in the interface and conducted informal tests. "Users were shown a set of images and told a word that should be associated with each of the images and users were given as much time as they needed to memorize the relationships. Then, under different contexts and in different spans of time, users were asked to recall the concepts or images associated with particular identifiers" (Parikh et al., 2003). The tests showed that users had difficulty using numbers to relate to concepts, but icons were much more successful. Researchers then proceeded to test their set of designs, modify the designs over two or three days based on their observations and suggestions and criticisms of the participants were re-tested. In this case the focus of the evaluation was on the improvement of the technology to improve ability of users to use the technology.

Chetty et al. (2004) used an iterative process to design a basic telemedicine to link the primary healthcare clinic with the nearest hospital in a rural village in Eastern Cape, South Africa. They first introduced a paper prototype and then proceeded to design and test the prototype. Interviews with doctors and nurses from the area as well as audio recordings of the system provided feedbacks. As in the previous case the focus was on improving the technology and facilitating better use by users.

In all of the above studies, the method used for data gathering was inquiry, which included field studies, interviews and feedbacks from the intended users, sometimes using an interpreter where the language of the users were different from the language of the researchers. McDonald et al. (2006) argue that "field methods can significantly improve downstream utility through the added value they provide in terms of the range of usability problems they uncover and the contextual information they yield on user difficulties and their causal explanations". The study used unstructured observation to observe participants at work in the student learning support department at the University of Sunderland. The study found that "the range of problems that can be uncovered by field testing extends far beyond those that would be uncovered in laboratory testing. The contextual data they provide on user's work and the causes of possible problems are likely to increase the possibility of finding workable solutions to uncovered problems".

The above research mainly focuses on involving the intended users. It is, however, also important to involve other stakeholders. In a study by Matthee et al. (2007) in Zambia, a number of organisations were involved in bringing internet connectivity to rural Zambia. The main stakeholders involved in international collaboration to provide internet in rural Zambia were the Meraka Institute ("a South African national ICT research centre managed by the Council for Scientific and Industrial Research"), Global Research Alliance ("the alliance of nine of the world's leading knowledge and technology research organisations"), TNO, which is the Netherlands Organisation for Applied Scientific Research, whose aim it is to strengthen the innovative power of industry and government and LinkNet, which has been a partner in the Global Research Alliance corporate program on development cooperation since 2006 (Matthee et al., 2007). In rural settings, the contributions by a group of stakeholders could improve solutions to a wider range of problems and create a wider awareness of the needs of rural communities. "The successful implementation of telecommunication services and the Internet in Macha was based on four key enablers: a holistic approach involving all stakeholders, including health institutions, schools and community members, training of local people for daily ICT operations and on-site support, affordable technology customized to local environment, central training and implementation at the LinkNet Centre of Experience at Maha" (Matthee et al., 2007).

2.5.2 System Evaluation

Ramachandran et al. (2007) found that "the presence of technology artefacts is important for understanding local attitudes toward technology and inspiring design ideas from populations with limited exposure to technology". The presence of technology artefacts allows researchers to "assess the technology baseline and market expectations of the community" and "appear to be useful tools in provoking stakeholders to share thoughts". Ashok and Beck (2007) also point out that many rural villages have little or no technology artefacts present. It can also be observed that many rural villages do not have many of the general office objects used as metaphors in computer software, for example writing materials, clipboards, files and many more.

The study by LaRose et al. (2007) used prototypes ranging from "numeric keypad-like devices to full desktop systems" to enlist comments from participants. "Interactive prototypes based on a standard screen resolution" were used during the second field trip (Parikh et al., 2003). The field tests by Ramachandran et al. (2007) used advanced stage prototypes. The interface of the Combadge Communication Device (CCD) used in their first field test was adapted to the local language via Tamil, the POS device for the microfinance services used in the second field test supported both online and offline transactions and the cameras used in the third field test were fully functional.

Kalra et al. (2007) designed and assembled a first version hardware prototype for a Braille writer and developed the software in close coordination with the intended users of the system. Different stages of the different components were evaluated. The literature therefore supports the idea that some kind of technology artefact, be it a paper model of the intended system, an advanced interactive prototype or a fully functional system should be used for evaluation.

2.5.3 The Evaluator

The users who will evaluate a system have to be selected. The question to be asked is what skills should the user evaluating the software have to facilitate the evaluation of computer software? Parikh et al. (2003) first explained the paper prototypes before getting feedback. They also allowed participants to familiarise themselves with the more interactive prototype on laptop before evaluating the system. The third field trip saw more extensive training and changes based on feedback. In all the field trips by Ramachandran et al. (2007), participants were first familiarised with the technology before feedback was sought. Chetty et al. (2004) used a familiar concept of cellular voicemail to base their telemedicine tool on, but also ensured that users clearly understood how the technology was to be used.

As many rural studies have shown, computer literacy in rural areas is low. Computer literacy training could improve users' ability to evaluate software. There have been many attempts to raise computer literacy levels in rural areas. This aspect in itself could be a challenge as Ashok and Beck (2007) note "digital artefacts are not a part of every walk of life" within rural communities. Furthermore, just increasing access to digital media does not necessarily mean that rural communities will adopt the technology, but learning from others within the community plays an important role in the adoption rate of the technology (LaRose et al., 2007). The absence of others within the community to provide learning experience could slow the adoption process down significantly. The research suggests that some training is required before the evaluation of the software could be attempted.

2.6 Evaluation at Design Stage

The question of whether users should be involved at system design stage is important as it could be an important factor influencing how well the needs of rural communities can be better met. Two scenarios are relevant, if the assessment takes place during development (Parikh et al., 2003), applications perfectly suited to rural populations could be developed, if the assessment takes place once the software is completed, only minor adjustments to accommodate rural communities can be made (Ramachandran et al., 2007). Both have distinctive advantages. If the applications that perfectly suited to rural communities are developed, would rural communities be able to transfer their knowledge gained by using this software to other applications, which were not specifically developed for their use?

Would this slow down their development and limit access to websites? If only minor adjustments are made to accommodate rural communities, it may take them longer to attain the required use of the software, but confronted with other similar looking applications could be less intimidating and broaden their possibilities.

Faulkner and Wick (2005) conducted an empirical investigation, using directed observation on a cross-user ability test approach. They grouped the users according to two factors, namely general computer aptitude and experience with the application being tested. The three levels were a) novice/novice, inexperienced computer users, users who have never used the application, b) expert/novice, experienced computer users, users who have never used the application being tested and c) expert/expert, experienced computer users and users who were experienced with the application. The study provided a way of quantifying usability errors and when comparing results from different groups, allows the designer to determine which of the icons "failed to provide intuitive or familiar software conventions, but the behaviour of that portion of the software could be learned with practice". This suggests that some usability problems should rather be corrected by redesigning while others should be corrected by teaching users. Usability errors that occur due to lack of experience, but where familiar software conventions have been followed, should rather be addressed by teaching to facilitate transfer of skills to other applications.

The development of specific applications for specific needs within communities, like the telemedicine system (Chetty et al., 2004), the Financial Management System (FMS) for micro-finance (Parikh et al., 2003), the Delivery Processing System and Representation and Inspection Tool (DPSRIT) for coffee producers (Schwartzman and Parikh, 2007) are all examples where rural communities were involved with evaluating from the beginning. They evaluated from paper models to advanced prototypes and were involved during every phase of the development. This enables designers to develop applications that address very specific needs.

Kalra et al. (2007) used action research in the development of hardware and software for teaching blind users Braille. They concentrated on using an iterative and participatory design process to create and refine a prototype Braille writing system, which contributed greatly to helping blind students understand the concepts involved. This application is very specific and involving teachers and students who would use the system, enabled designers to identify problems specific to the application itself and also the context of use.

The literature therefore indicates that more general applications could be evaluated later and some usability errors addressed by teaching, while more specific applications should be evaluated from initial stages, continuing throughout the development of the application.

2.7 Support for ICT in Rural Settings

ICT is widely touted as a potent means to strengthen rural governance and citizen participation, rural development, rural poverty reduction, improve the livelihoods of the poor and the segregated community through comprehensive ICT development programmes that provide on-demand access to locally relevant knowledge in diverse domains including health, agriculture and public services provisioning (Soriano 2007; Sattar, 2007). The ICT support in rural communities is well served through the interdisciplinary approach of Community Informatics (CI). The notion of CI refers to an emerging field of investigation and practice that is concerned with the ICT principles, which focus on personal, social, cultural, political and economic development of communities. CI addresses the impacts and utilisation of ICT to facilitate community life through a participatory design approach. Participatory design is the direct involvement of end-users and stakeholders in the design and development of information systems, applications, infrastructures, services and associated work practices (Carroll and Rosson, 2007).

Provision of internet connectivity and ICT infrastructure required a huge up-front investment (Matthee et al., 2007). Pringle and David (2002) argue that "rural ICT requires special efforts to create appropriate models for those who can neither afford the internet access, nor have the language capacity to understand the content". A case study by Pade et al. (2006) into ICT project sustainability in rural areas differentiates between financial sustainability and "sustainability". The concept of sustainability encompasses more than just the financial or economic aspect of the project, but also considers other significant facets such as rootedness in local communities, cultural and political acceptance and value to rural individuals (Pade et al., 2006). Rural populations should therefore evaluate computer software in terms of the applicability of the software within the rural context, user interface communication and sustainability within the rural community.

2.8 Literature Summary

A common theme found within most studies is that of participatory design for user interfaces. Participants from the target user group participated in the design in terms of evaluating the system, leading to further iterations of the design phase. Designers communicated in different ways with the intended user group. Designers can benefit from a participatory design process (Keates et al., 2000; Ashok and Beck, 2007; Ramachandran et al., 2007) and intended target group can also benefit from such a process (Matthee et al., 2007; Parikh, 2007). Another important theme that emerges from literature is that evaluations took place in the actual context of where the system was to be used (Parikh et al., 2003; Ramachandran et al., 2007). However, the really more important aspect that can be noted is the role of culture in the usability of the interface for rural users (Evers et al., 1999; Ferreira et al., 2006; Lindberg et al., 2006; Wang, 2007).

The work reported in this thesis is unique, although the work identified challenges within rural settings, using some similar approaches, the proposed solution is a holistic aproach to identifying problems. The TSM approach encoumpasses much more than just a few field trips with unstructured evaluations. The model for the development of HCICI, which is proposed, not only tests the solution, but also investigates user support for the solution. This becomes apparent as technology support is more of a political issue in most communities in the developing countries. A technology, no matter its level of novelty, it might polkitically not be supported for adoption in a certain community.

Chapter 3 Preliminary Study on User Interface Usability

A preliminary study of ICT penetration and user interface usability issues was conducted in a rural setting in South Africa. The purpose of the preliminary study was to gain more insight and familiarity with the issues of ICT penetration and to better comprehend those issues affecting the effective utilization of ICT among African rural users. This provided a clear insight for the development of a research model to empirically uncover the specific factors that are required for a wider utilization of ICT in rural settings. In doing this, a framework based on the synthesis of cultural probes and bodystorming was first developed to guide this preliminary study. This also was to confirm the hindrances to ICT penetration in rural settings as identified by the literature study. The choice of this integrated methodology is suitable for describing and evaluating the performance of ICT programmes in their natural settings (Mouton, 2001). This was to also allow the research team to work within an environment with the natural limitations often associated with rural settings. Mutual trust had to be developed and an interpreter was extensively used to ensure that language did not become a barrier.

This study, although exploratory in nature, shows the level of participation of users when they are involved in the evaluation of options presented to them. In order to be able to determine whether the needs of rural users are met when contributing to system design, it is important to engage users in the design process. The focus of this study was on the interaction between users and the design team and what would encourage users to interact and make significant contributions to the system design. Other than the distance and preferred communication method, which makes usability testing more difficult, there was no indication that inexperienced computer users in rural settings require different approaches than inexperienced computer users in urban settings when designers plan to involve users. The availability of support such as computer skills training in rural settings could however, prove to be another obstacle to rural communities. In this chapter, the concepts of cultural probes and bodystorming are introduced to provide sufficient foundation for the readability of this thesis.

3.1 Cultural Probes

Cultural probes, as described by Gaver et al. (1999) are a research approach to obtain unstructured information about users and their backgrounds. It involves using some interactions and probes to encourage users who are culturally different from the designers to express their thoughts and allow ICT system developers to have greater insight within the context of the intended system. Cultural probes are used to gain more insight into the backgrounds of the participants. The core of the cultural probes approach is to give people suitable tools to document, reflect on and express their thoughts on environments and actions (Hulkko et al. 2004). Probes are collections of evocative tasks meant to elicit inspirational responses from people, but not comprehensive information about them (Gaver et al., 2004). There are different approaches that can be used for the construction of probes. However, probes could be artefacts, pictures, metaphors and any kind of interaction styles. The important benefits of using probes are to help ICT system designers to:

a) Effectively use unstructured data to better understand the experiences and needs of the target user group.
b) Gain insight where traditional methods could possibly ignore important issues because of the characteristics of the target user group.

3.2 Bodystorming

The concept of bodystorming, which is also known as physically-situated brainstorming, is an interaction design method for carrying out design sessions in the original context, without much emphasis on a specific industrial location for the design work (Burns et al., 1994; Oulasvirta et al., 2003). The method also naturally applies to seek an improved solution to any kind of problem, provided the people concerned with seeking an improved solution to the identified problem are involved in the solution process. A location is usually selected that is identical to the original environment for the onsite workers to commence work. The innovation that is carried out on-site is based on ethnographical data presented as concrete design questions. A design question represents the phenomenon as a problem in the events, experiences or practices of users. Individual solutions to design questions are brainstormed and discussed on-site and on-site workers can be helped to contribute to specific problems by answering a set of questions. Facets of data collection and preparation, formulation of design questions, selection of locations, session administration and evaluation of design ideas are presented.

There are different variants of the bodystorming methods such as embodied storming, which has recently been proposed for interaction designers to engage with unfamiliar contexts (Antle et al., 2009; Schleicher et al., 2010; Isbister, 2011). This developed into a user experience design paradigm as a way of capturing user experience, perception, affection and valuable aspects of human-computer interaction. User experience has been identified as a key concern of services and products development, which is not only about implementing features and testing their usability, but also about designing services and products that are enjoyable and support basic human needs and values (Väänänen-Vainio-Mattila et al., 2008). In the user experience movement, researchers and designers aim at a more holistic understanding and evaluation of interaction encompassing, beyond mere cognitive or ergonomic issues, for example enjoyment, pleasure, emotional and cultural aspects (Editorial, 2006).

The benefits of the bodystorming method include the following (Godden and Baddeley, 1975; Zhang and Norman, 1994; Burns et al., 1994; Chun and Jiang, 1998; Oulasvirta et al., 2003), because of being physically present:

a) Immediate feedback for the generated design ideas.
b) A more accurate understanding of contextual factors.
c) A suitable approach for designing activities that are inaccessible and unfamiliar to the researchers.
d) A reduction in the amount of time needed to study documents of user observations.
e) Enhanced design ideas by permitting the evaluation of invented design ideas already on-site.
f) Easier simulation and testing of the generated ideas and less error prone.
g) Freed up mental resources for decision making, problem solving and reasoning needed in the design phase.

3.3 Cultural Probes and Bodystorming

Cultural probes and bodystorming were applied, which are two important participatory methods in HCI studies to engage African rural users in understanding the challenges of usability. The synthesis of bodystorming and cultural probes methodology can support design sessions in the real context of users rather than the lab (Oulasvirta et al., 2003). In applying the methodology, easily readable design questions are generated to capture the events, experiences and practices of users. This method requires the system developers to go to a representative environment where participants attempt to solve one question at a time in the actual cultural context. The cultural probes (Gaver et al., 1999) are made up of packs of different objects and materials that are designed to promote informative responses from people with diverse cultures. The proposed methodology can be applied to user interface usability studies by following the principles enunciated as follows:

a) Location selection – the location where the usability study will be conducted should be carefully selected and should be such that it is close to the proximity of the end users of the system. The team of developers should be prepared to conduct the usability study off-site instead of on-site, which is usually the developers' site. Off-site is a neutral location that is in close proximity to the real users of the system. This location should be decided by the users and not the developers to enable wider participation of users and to allow them to have some feelings of complete ownership of the system. In a nutshell, the system developers should play the role of a Mobile Work Force (MWF) to realize full user participation and satisfaction. The concept of MWF is defined as a group of mobile or adaptive developers, prepared to carry development activities to the organization and environment of the real users (Olugbara and Adebiyi, 2007). According to the principles of MWF users are asked to provide a makeshift office and the necessary infrastructure to enable MWF work.

b) Role responsibility – there should be a clear delineation of responsibilities between a team of software developers and the ultimate end users of the system. The principle of tasks partitioning (Olugbara and Adebiyi, 2007) should be applied to improve the quality of usability evaluation. According to this principle usability evaluation tasks or activities resulting from usability stories or probes are grouped. Each group of tasks is then assigned to a group of members depending on the complexity of the tasks and the ingenuity of the group members. The group containing the most difficult tasks should be assigned to a group with more experienced members, while a less experience group is assigned less complex tasks. As the evaluation progresses, group members are moved around to work on different tasks. The users should be encouraged to fully participate in problem solving tasks and freely express usability concerns as perceived. The system developers should not try to convince or justify the reason for a particular implementation, but listen to the views of the users. As a result, the methodology enables developers to know the real users of the systems. Moreover, the process of knowledge sharing is highly facilitated, because developers and users would benefit from the participatory interactivity.

c) Tool support – the usability testing session should rely on tool support for productivity enhancement. There are various methods and tools for identifying system usability problems and many of these methods can still be used. The notion of usability testing simply means conducting experiments to discover specific information about a design problem. The experiments usually define a set of questions or hypotheses, which are suppositions made as a basis for reasoning or as a starting point for further study from known facts. Then a clear method is selected or developed to answer the questions. There are a number of usability testing methods available in the literature and examples are usability inquiry such as ethnographic study, interviews, focus groups, surveys (Rubin, 1994; Rose et al., 1995; Kirakowski, 2003; Qui et al., 2007), screen snapshots (Thompson et al., 2004) and usability inspection such as cognitive walkthrough (Polson et al., 1992; Hollingsed and Novak, 2007), Pluralistic walkthrough (Bias, 1991; Hollingsed and Novak, 2007), feature inspection (Bell, 1992; Nielsen, 1994) and formal usability inspection (Hollingsed and Novick, 2007).

d) Cultural dimensions – there should be total emphasis on cultural issues. Culture is a concept that captures the values and behaviour of a group of people in different contexts. Cultural dimensions are models to describe the behaviour of the members of different cultures and support quantitative analyses of characteristics of different groups (Hofstede, 1991, Heimgärtner et al., 2008). This implies that behaviour of African users would be studied to determine how they would naturally act or react to the current office metaphors. In assessing the behaviour of African rural users on how they would naturally react to selecting alternative interface concepts, a literature study was conducted to identify African utensils and objects that are common to rural African villages. The traditional uses of these utensils and objects were assessed with the particular aim of intuitively linking these objects to possible computer actions. The objects that were selected were as inclusive as possible and not gender orientated.

e) Training support – user training is an important principle of this methodology and developers should be willing to provide such support. As a result, anyone contemplating the development of a system for effective utilization, must have a conception of the intended users group, tasks that those users want to perform with the system and how they would like to perform those tasks. Problems often do arise simply because the system developers do not recognize discrepancies between models and reality. In order to effectively reduce these discrepancies, the role of system stakeholders in the development process is important. The provision of training support can assist the real users to contribute more significantly to the development process. This is because training will enable users to have a better understanding of the system and therefore put the users in a better position to make more meaningful contributions. Many HCI studies have noted the importance and use of training to facilitate changing, expanding and building users' mental models of the system and the potential tasks performed by the system (Carroll and Carrithers, 1984; Orlikowski, 1992).

3.4 Case Study

This section reports on a case study of how the methodology based on cultural probes and bodystorming was used to gain insight into usability issues from an African rural setting perspective. The specific aspects that were studied are the level of user interface experience, whether rural participants with a basic level of computer literacy have the ability to evaluate a user interface, language of the user interface, preferred communication channels to communicate user interface needs through and the ability of users to evaluate user interface objects.

The preliminary study targeted small enterprise owners in a rural setting, specifically focussing on their accounting practices to try and find a similar context. For the preliminary study on usability, small enterprise owners were selected from the rural community of Umbumbulu on the South Coast of KwaZuluNatal province in South Africa. Some parts of the area are sparsely populated, while other parts are more densely populated. The area is subdivided into eight regions, each administered by a traditional leader, the Induna, who in turn is responsible to the area leader, the ‘Nkosi. Permission and support for the research was obtained from the ‘Nkosi by the project leader. This area was selected because it contains a mixture of peri-urban and rural settings under traditional leadership. Figure 3.1 shows the landscape characteristics of the onsite study area.

Figure 3.1: The characteristics of the area

The preliminary study was conducted in an environment, which was unfamiliar to the research team. This is a perfect principle of the methodology to understand the context of being with the real users. Figure 3.2 shows a Multi-Purpose Communication Centre (MPCC) equipped with 10 computers that was used to conduct the preliminary uswr interface evaluation study.

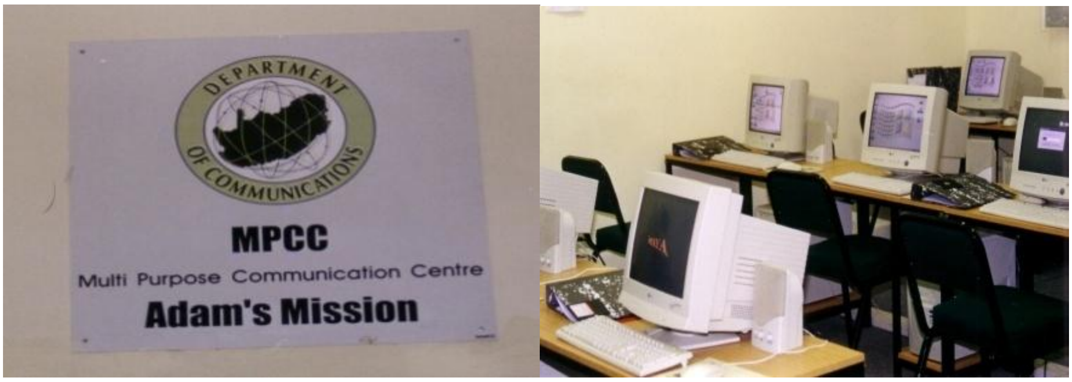


Figure 3.2: The MPCC where the participatory interaction took place

3.4.1 *Participant Selection*

The owners of small enterprises in Umbumbulu were chosen as a population because a clear purpose for using ICT could be identified, which would encourage meaningful participation. As small enterprise owners are familiar with the practices of an enterprise, it was assumed that they would have some domain knowledge. An open source accounting package, Lazy8ledger, which could assist with the activities of a small enterprise was therefore chosen as an instrument through which participants' ability and willingness to evaluate a user interface and involvement with changing the user interface could be assessed. The project team, of which the researcher was a part, identified the sample frame for the project, using questionnaires. As many of the owners of small enterprises as possible were identified using the help of the Indunas, who are each in charge of a section of the area. Figure 3.3 shows an example of small enterprise owners that participated in the user interface evaluation study.

Figure 3.3: Small enterprise owner

The method of selecting participants from the sample frame for the first round was prescribed by the 'Nkosi. This was done to involve participants from the whole area and not favour a specific group. Each of the 8 Indunas from the area had to identify the participants from his area. In an attempt to be as representative as possible within these constraints, each Induna was asked to identify 5 participants, therefore a total of 40 for group 1. The only constraint imposed by the researchers was that participants had to be able to read, but no formal school qualification was needed. The literacy levels of the participants were however not tested in anyway. The sampling method therefore was judgement sampling as described by Stuwig and Stead (2001). The judgement criteria used by each Induna was unknown. Although this was not as scientific as required for an academic approach, it was regarded as acceptable in view of a second, third and fourth group being trained and tested.

For the second, third and fourth groups, application forms were distributed throughout the area. During the first round of training, it was noticed that some of the businesses owned by the participants were very small with no accounting system. In order to address this problem, the size of the business was considered. Prospective participants had to indicate their level of schooling and the types of enterprises they owned. These two factors were used to select participants for the second, third and fourth groups. The size of the business was an especially important factor, as a paper trail of some sort was required to use an accounting system. The concept could better be explained when a paper trail is present. The sampling method was also judgement sampling, in this case the judgement of the research team based on the above criteria was applied.

The gender factor was considered because gender is one of the key divides in rural communities. The gender statistics obtained through the attendance registers were as follows. For the first group 39.4% were male and 60.6% were female. For the subsequent groups combined, the breakdown was similar with 35.8% male participants and 64.2% females. The higher number of female participants could be ascribed to more females in rural areas not being able to secure employment outside the area.

Table 3.1: Data gathering activities

Group	Task
1	User level questionnaire, interviews, training, facilitator, language
2	Training, test, icon identification
3	Training, test, icon ranking
4	Training, test, expectation questionnaire

The first group comprises of small enterprise owners whose user interface experience levels were assessed by a questionnaire. Very little was known about their computer and business skills or what accounting systems were used. It was anticipated that their computer literacy level would be low, which was confirmed by the first questionnaire. Subsequent groups were not asked to complete this questionnaire as this group comprised 27% of all the participants and were regarded as representative in profile of all the participants. The questionnaire used questions to determine participants' level of user interface experience in communication with devices such as Automatic Teller Machines (ATMs), cellular telephones and computers. This was important as the level of user interface experience could impact on the user's ability to identify problems with the user interface. Users may assume that the difficulties they encounter are due to their lack of skills, while it may be due to a problem with the interface. Involving users with a low level of user interface experience without improving their experiences was considered to be useless and could prove very intimidating to the participants. As this was the first research of this nature taking place in the area, it was considered to be very important to gain the trust of the community.

All participants (groups 1-4) were given 4 weeks of 2 hours per week computer literacy training. The training covered very basic concepts in the use of Windows, Microsoft Word, Microsoft Excel, Outlook Express and Internet Explorer. All of these aspects are broadly regarded as essential for basic computer literacy and were chosen for this reason. It was also regarded as important to expose participants to more than one user interface and therefore a selection of programmes rather than only one programme was decided upon. Excel was specifically included as it would be used to illustrate some of the business and accounting skills to be taught by other members of the project. After the computer literacy training, business management and accounting sessions commenced for each of the 4 groups. During these sessions, Excel was again used to teach certain business concepts and the Lazy8edger accounting package, which was translated into the local language was introduced. There were 8 sessions of 2 hours each. The fact that a large financial institution such as ABSA changed ATM interfaces to allow for the selection of a preferred language suggested that language is an important factor in understanding a user interface. Google has also made the option of searching in five of South Africa's eleven official languages possible.

The most common language found within the geographical area of Umbumbulu is Zulu, which was used for this preliminary study. The accounting package was selected from open source software and could be adapted as required. The package was translated into Zulu. A second questionnaire was used to assess group 1 participants' reaction to a Zulu interface as well as their understanding of some aspects of the user interface. It must be emphasised that this was not a usability test of the package as opposed to the English interfaces of the other packages. It was merely used to determine user responses and attitudes towards a Zulu user interface. For group 1, another questionnaire, completed by the facilitators after the computer literacy and the business skills training, determined the success of improving participants' skills based on the facilitators' observations. In order to minimize the fear of computers and the new situation, it was decided that for the first group a questionnaire for the facilitators would be more suitable to determine the success or failure of the training in raising the level of computer literacy of the participants. Although it could only measure perceptions, it could at least give an indication as to whether the training was on the right track or not. This would mean that the training was suitable to be used for all the following groups. The subsequent groups did a formal test on computer to determine the actual understanding of the participants.

Thirdly, group 1 participants were interviewed to determine their preferred channel of communication about user interfaces. Semi-standardised interviews offer the opportunity to be less formal and could be more conducive to participants speaking freely, especially in an unsophisticated environment (Struwig and Stead, 2001). Interviews were used to get feedbacks from participants on preferred communication methods and other aspects of the user interfaces used. The interviews were conducted in the laboratory where the training took place. The use of a familiar environment was to keep participants relaxed. Each participant was interviewed in front of the computer so that when questions about an application were asked, it could be activated and be visible during the interview. Where needed, an interpreter was used. Although all participants were asked the same questions, the questions sometimes had to be rephrased and examples given. Where examples were given, the same were given in each case.

Two more rounds of training and testing took place, while the fourth round was completed by the end of 2005. As a result, 4 groups of participants wherein 20 members form a group, except for the 4th group with 19 members, were trained. Computer literacy testing for groups 2, 3 and 4 were conducted after the training. The second group of participants were asked to identify some icons that proved difficult. The third group was asked to rank different icons for the "undo" action and to design an icon for undo. A questionnaire was used to determine the expectations of the fourth group. The questionnaire posed questions as to what changes the participants thought computers could achieve, such as whether using computers would decrease crime, reduce employment opportunities and other related social problems.

3.4.2 Case Study Result

The initial results of the case study include user interface experience, raising level of user interface experience and computer literacy, language perceptions and attitudes, icon understanding, evaluation and design and preferred communication channel. The first questionnaire was used to profile participants in group 1 with regard to user interface experience. Figure 3.4 shows the percentage of participants who have used a computer, cellular telephone and an ATM before or none of these devices. The result shows that almost 25% of the participants from group 1 had not used a computer, ATM or cellular telephone in the past. This was considered to be very high and a little unexpected. During negotiations with the Indunas, many cellular telephone kiosks were observed and cellular telephones appeared to be well supported. However, almost 25% of the participants' user interface experience was clearly very limited.

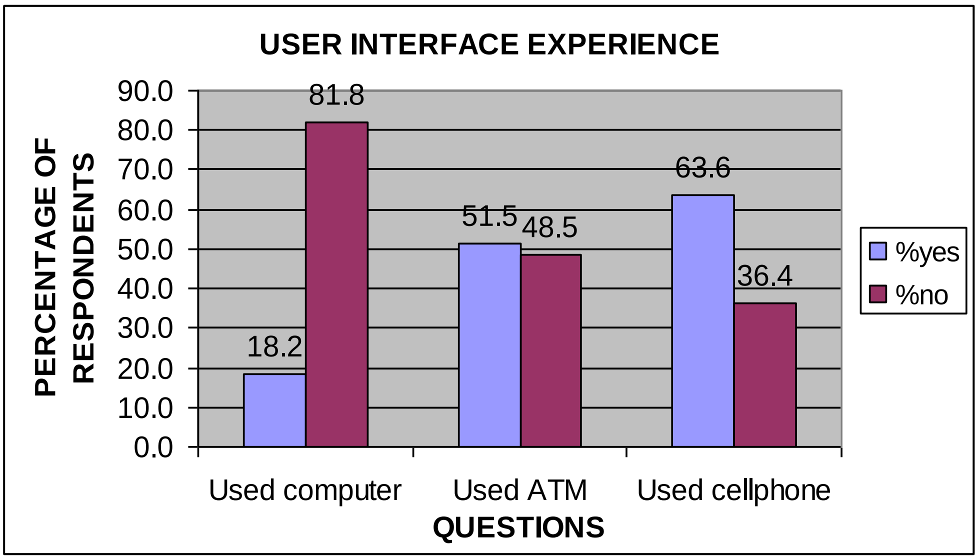


Figure 3.4: User interface experiences

Figure 3.5 shows the distribution of participants from group 1 who have used one or more of the devices. It was clear that these participants had a far better exposure to cellular telephones than to computers. It is common knowledge that majority of cell phone users, regardless of education level used only a small number of the available features and functions of the cell phone. The questionnaire therefore also attempted to determine the level of user interface experience. Questions about adding a name to the phonebook, programming a reminder and calling the last missed call number were included. Of the group who had used a cellular telephone, many of them did not know how to add a name to the phonebook, program a reminder or call the last missed call number. Only 28.5% of those who had used a cellular telephone before could do all three. Programming a reminder proved to be the most unknown facility. The responses to ATM and computer sections of the questionnaires supported the findings for the cellular telephone. This questionnaire highlighted that level of user interface skills of the group was very limited. This group could therefore be used to determine their contributions to the design and evaluation of a user interface.

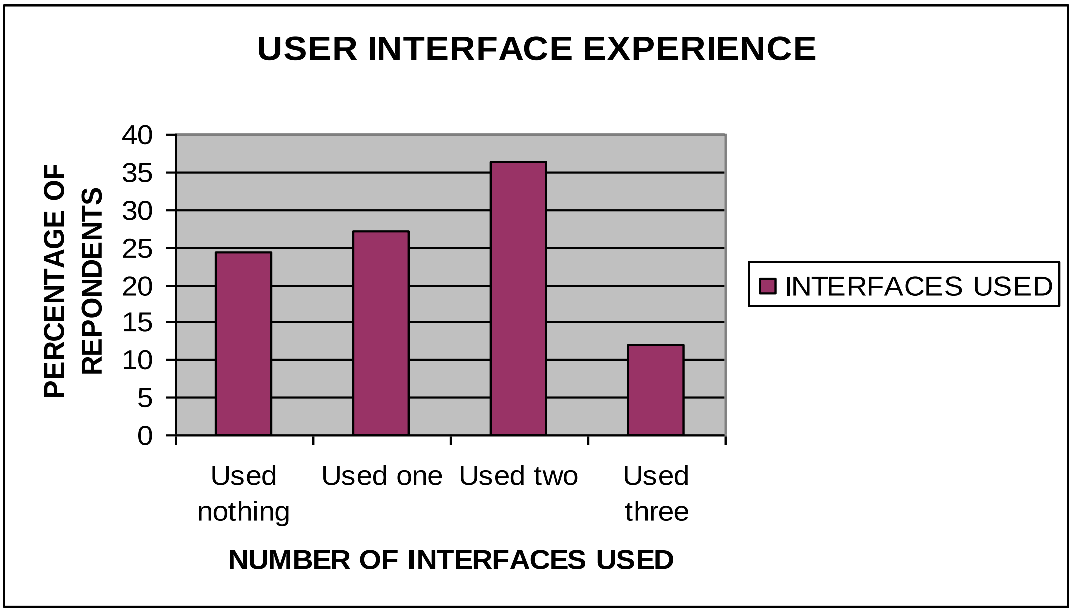


Figure 3.5: Number of interfaces used

While training took place, three facilitators offered general support and helped with translating instructions and explanations where necessary. Although certain tasks such as saving a file to disk were done repeatedly in each of the sessions. It was noted at the end of the computer literacy training that some participants still had difficulty to accomplish these tasks without help from the facilitators. This indicated that although the level of computer literacy was raised, participants were not capable of independent computer use. This may be due to lack of practice between weekly sessions. At the end of the course for group 1, each of the facilitators completed a questionnaire about their perceptions. The questionnaire tried to determine how well facilitators thought the participants understood the Excel concepts of File, Formula and business concepts of Debt and Asset. A scale of 20%, 40%, 60%, 80% and 100% of participants was provided. If a facilitator marked 20%, one mark was assigned, if marked 40%, two marks is allocated and so on. These marks were taken out of 5 for each facilitator and converted to a percentage. Figure 3.6 summarizes these observations.

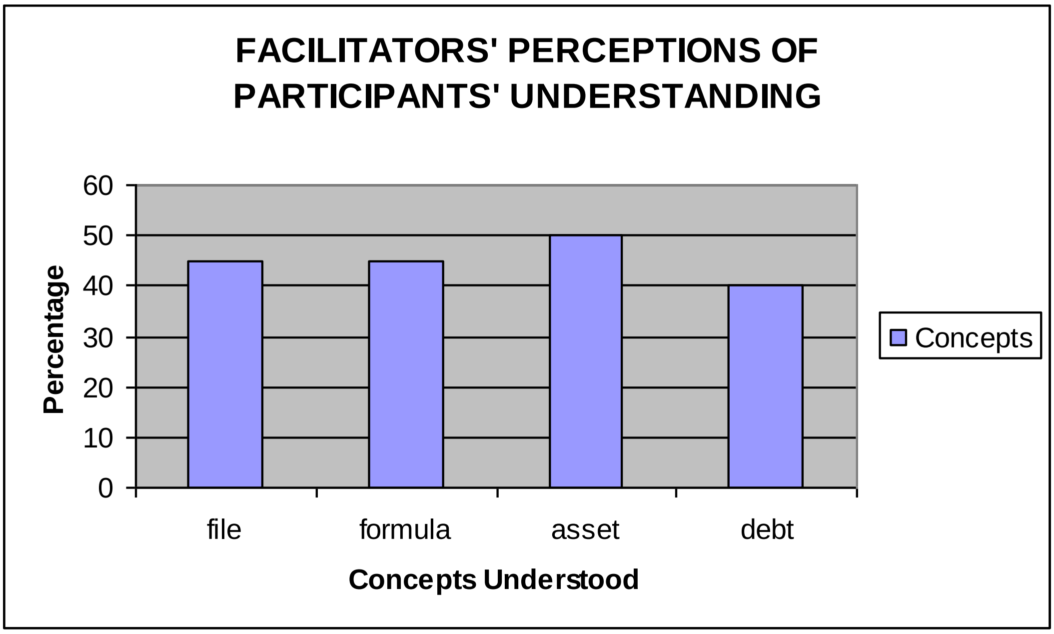


Figure 3.6: Facilitators perceptions

After the training, the facilitators thought that the level at which participants could operate independently was below 50%. Although the levels of computer literacy and business skills were raised, it was still not at a level where participants could work without support. Because this could only give the facilitators' perceptions, the subsequent groups were formally tested and although the computer literacy of participants had been raised, it still did not allow for fully independent computer activities. However, the training gave participants a uniform level of computer literacy as all groups received the same training.

The second questionnaire that group 1 participants had to complete dealt with their perceptions and attitudes towards using a Zulu interface, as well as their understanding of the interface as a result of the Zulu interface. Figure 3.7 shows the responses in the questionnaire towards the use of a Zulu user interface in the accounting package. More than 80% of the participants agreed that having a Zulu interface promoted their understanding of the interface and also helped them to remember better. Almost 70% thought that what they had learned could be transferred to other user interfaces, yet more than 60% indicated that they would prefer it if the interface was in English. The perception of your skills regarded as superior if you could negotiate the user interface in English language as opposed to an indigenous language such as IsiZulu.

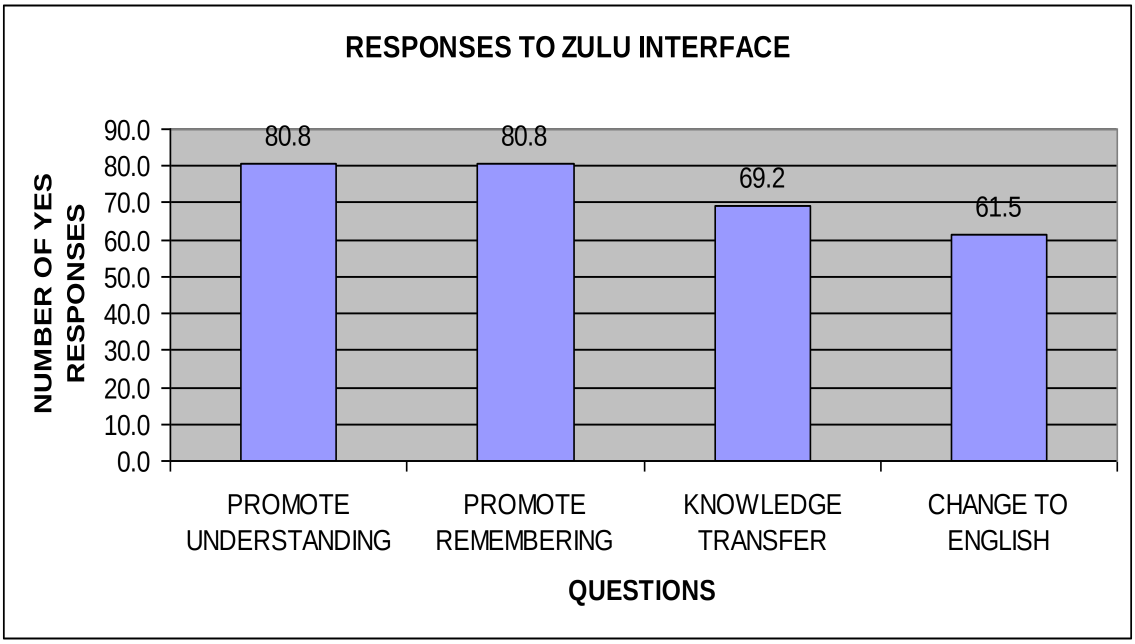


Figure 3.7: Language perceptions

The interviews also attempted to determine preference for an English user interface or a Zulu user interface. Windows, Microsoft Word, Microsoft Excel and Outlook Express were in English, but the accounting package was Zulu. Participants were asked what they would like to see changed in Excel. They were prompted to consider the language, some of the icons and the colours. Only two participants chose to change the language. The two participants who wanted the language changed had to make use of an interpreter during the interview. It is therefore to be expected that they would prefer a user interface in their own language. Participants were also asked the following question. What made the accounting package, which was in Zulu difficult or easy to use? Here participants were divided as to whether the Zulu interface promoted or inhibited understanding. The criticism was that the Zulu terms were often much longer than the English and this made the menu items too long. Another was that having learned the terms that are general to most packages, like the File options, in English, they now had to relearn the Zulu version. Others indicated that the Zulu contributed towards a better understanding of the basic concepts, which could be transferred according to the participants into other English user interfaces.

Group 2 participants' understanding of some icons was tested. The icons for a new document, incorrect action, printing the document, undoing the last action and cutting were tested. At least two of the icons, an incorrect action and the icon to undo the last action were not well recognised, although these icons are similar to the icons used widely in Micro Soft applications. The third group of participants was given 5 icons that could represent the undo action and asked to rank these icons. Figure 3.8 shows the list of the icons.

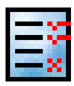
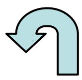
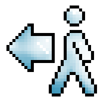
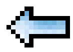
	Participants were given undo icon to rank its close resemblance to five other icons			
1	2	3	4	5
				

Figure 3.8: Icons to rank

From this result, it was clear that icon number 2 was ranked the best as an undo icon and icon 4 the second best. Both icons use arrows and the concept is similar to the Microsoft undo icon. What is however more important is that participants had clear ideas about which icons did represent the action and could evaluate options presented to them. When group 3 were asked to draw a picture to represent the undo action, 40,7% of the participants drew some kind of an arrow, 29,6% drew alternative pictures that could represent the undo action, while 29,6% drew pictures not related to the undo action. This means that once participants had seen examples of icons representing the undo action, only 29,6% presented an original representation of the action. When the members of Group 1 were asked during the interviews about the icons in Excel, one of the participants explained that if you only know one option and have not been exposed to other options it is very difficult to evaluate or suggest improvements to the icons. It appeared that when the function of the icon was explained, it was accepted, irrespective of the picture representing the icon. This clearly indicates that a higher level of user interface experience is required for users to be able to participate in the development of a user interface. They were however able to indicate clear preferences when presented with alternatives.

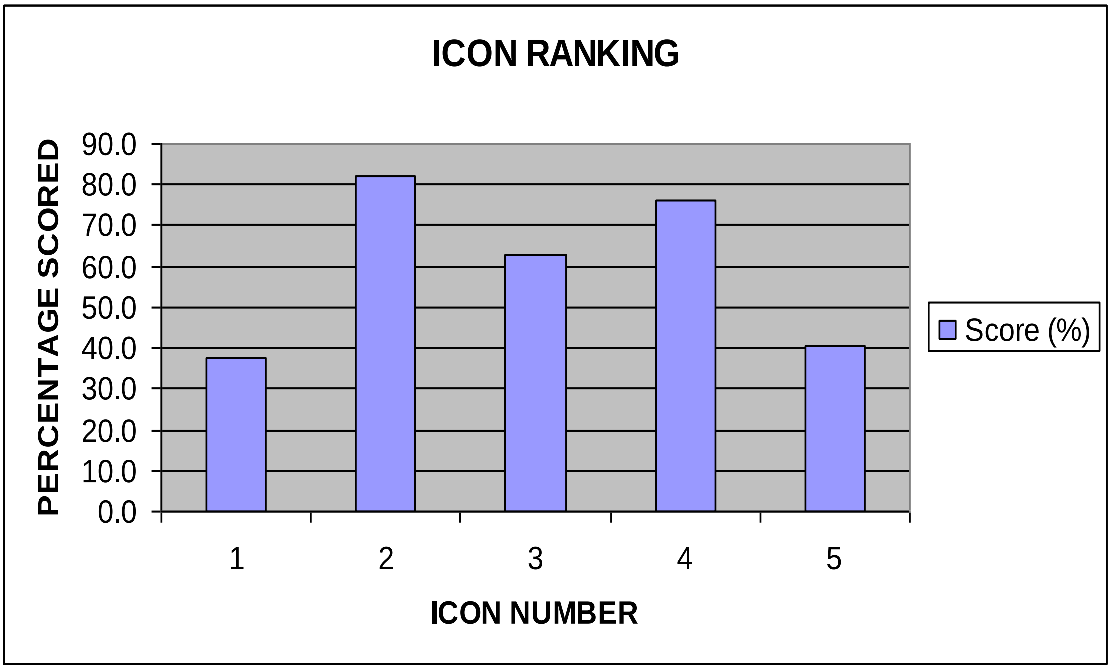


Figure 3.9: Icon ranking

3.4.3 Interpretation of Results

The first questionnaire established that user interface experience levels of Group 1 were low, therefore the group was suitable to use for the study. Once word of the nature of the training spread, subsequent groups were also groups who required computer literacy training as established during the training, so it could be assumed that their experience levels were similar.

The second questionnaire completed by the facilitators indicated that level of computer literacy for group 1 had been raised, although not to the level of independent work. Subsequent groups were formally tested to confirm this result. In order to raise the level of computer literacy to the standard of independency, a longer intervention is possibly needed. The training therefore only provided a uniform level of computer literacy for all the groups.

The third questionnaire completed by group 1 participants was supported by the interviews to test participants' reactions to a Zulu interface. Participants were prepared to express clear views towards the language aspects and could clearly motivate their viewpoints. The results indicate that as with some of the current ATM user interfaces, users should be able to choose their language of preference. Designers should design user interfaces for a multi-language user population.

The icon understanding, ranking (Group 2) and design exercise (Group 3) determined the type of contribution that users with a low level of user interface experience could make. Designers should focus on usability testing at different stages of the design, rather than involving users in the design of the user interface.

The last aspect, preferred communication channels was included because rural communities were the target. Some rural communities in remote areas might be difficult to reach and if email or some method of communication other than face-to-face could be found, it could make usability testing easier. The results however show that users prefer face-to-face communication. Participants had to be prompted to evaluate and criticise the interface. With limited user interface experience users are unsure of what could be changed, making it more difficult to suggest changes. In a face-to-face evaluation of the user interface, the designers could suggest areas of change and thereby with the help of the users identify problematic areas.

Chapter 4 Empirical Study on User Interface Usability

This chapter reports on empirical study of user interface usability. The purpose of the empirical study was to develop a comprehensive research model and hypotheses to answer the research questions raised. The impetus and inspiration to develop and test a research model and a set of research hypotheses originated from the outcome and insight gained from the preliminary study on user interface usability. The empirical study is generally premised on the assumption that interface users are people with diverse cultural backgrounds, environmental settings, technology competence and social-economic heritages. In order to design user interfaces that would be easy to use by a wide range of users with various levels of knowledge, skills and from different cultural backgrounds, the concept of culturally adaptive systems was proposed to substantially increase usability (Heimgärtner et al., 2008; Vasilyeva et al. 2005; Kobsa, 2000). The main objective of cultural adaptive systems is the situation-referential adaptation of cultural aspects, for example graphical and speech interfaces (Heimgärtner et al., 2008). Vasilyeva et al. (2005) view adaptive user interfaces as an opportunity to address the challenges of having "a group of users, having their own individual abilities, interests and needs" in eHealth projects.

4.1 Research Model for the Empirical Study

In order to determine how much users have understood the effective use of interface systems, it is important to assess their technology competence. This will allow for a better understanding of how to identify the knowledge and skills they have gained during the interaction sessions and to justify the need for alternative system concepts. Specifically, the researcher assessed the domain-general cognitive ability that has to do with working memory and attention control (Welsh et al., 2010). In general, cognitive skill can be defined as the capacity to process information and apply knowledge. Cognitive skills are generally measured by tests such as an intelligence quotient test and cognitive skill tests such as the one used in this thesis. Significant advancements have been made in intelligence theory and testing technology that have the potential to provide a better understanding of cognitive abilities. For this study, an empirically supported measure of the constructs within the Cattell–Horn–Carroll (CHC) theory (Cattell, 1967) of cognitive abilities is used to analyse the contribution of specific cognitive abilities of African rural users to associate alternative metaphors with computer actions.

There are a variety of intelligence theories grounded in markedly different research traditions that have received increased attention in recent years. Examples are CHC theory of cognitive abilities, Gardner's Theory of Multiple Intelligences, the Luria–Das Model of Information Processing and Sternberg's Triarchic Theory of Intelligence (Vanderwooda et al., 2002). CHC theory is considered a strong alternative to a general ability approach to intelligence testing (Reschly, 1990; Carroll, 1993; Vanderwooda et al., 2002). In the CHC model, cognitive abilities are classified at three strata that differ in degree of generality (Carroll, 1993). Several of the broad cognitive abilities in the CHC model are fluid intelligence, crystallized intelligence, short-term acquisition and retrieval, visual intelligence, auditory intelligence, long-term storage and retrieval, cognitive processing speed, correct decision speed and quantitative knowledge (Vanderwooda et al., 2002).

A brief description of these cognitive abilities as given by Vanderwooda et al. (2002) is as follows. Fluid reasoning or intelligence is measured by tests that require inductive, deductive, conjunctive and disjunctive reasoning to understand relations among stimuli, to comprehend implications and draw inferences. Acculturation knowledge, which is also called comprehension knowledge, is measured by tests that indicate the breadth and depth of the knowledge of the dominant culture. Quantitative reasoning is measured by tests that require understanding and application of the concepts and skills of mathematics. Short-term comprehension/retention, which is also called short-term memory, is measured with a variety of tests that require maintaining awareness of and recalling elements of immediate stimulation. Fluency of retrieval from long-term storage, which is also called long-term memory, is measured by tests that indicate consolidation for storage and require retrieval through association of information stored minutes, hours, weeks and years before. Visual processing is measured by tests that involve visual closure and constancy and fluency in imaging the way objects appear in space as they are rotated and flip-flopped in various ways. Auditory processing is measured by tests that involve the perception of sound patterns under distraction or distortion, maintaining awareness of order and rhythm among sounds and comprehending groups of sounds such as chords and the relationships among such groups. Processing speed is part of almost all intellectual tasks and is measured most purely by tests that require rapid scanning and responding to intellectually simple tasks that almost all people would get right if the tasks were not highly speeded. Correct decision speed is measured by tests that require quick answers based on thinking.

4.1.1 Miller's Competence Pyramid

This study concerns the assessment of the acculturation knowledge and visual processing cognitive skills of participants. Using this assessment method, a set of survey questions was presented to participants to determine their relevant background knowledge of user interface systems and their applications for business performance improvement. This method assists the researcher to gain an overview of how effectively African rural users are able to interact with ICT systems and how they apply the systems so as to identify areas of weakness. A survey is a suitable instrument to assess the cognitive skill of users to associate the selected African village metaphors with computer actions. The purpose of this action was to determine whether an adaptive user interface can be realized by replacing those office metaphors by African village metaphors.

The constructs of Miller's competence pyramid (Miller, 1990), "knows", "knows how", "shows how" and "does" were investigated to determine African rural user behavioural support for alternative concrete metaphors as interface icons. In this study, behavioural support means the willingness of users to accept, use and promote alternative village object metaphors as interface icons. Miller's pyramid, which is composed of four levels of knowledge constructs, "knows", "knows how", "shows how" and "does" (Miller, 1990), was applied in this study to discriminate between knowledge, comprehension, skills and performance. These knowledge constructs were explored to build a Technology Support Model (TSM) for assessing the behaviour support of African rural users for alternative concrete metaphors. The study presupposes that the support of African rural users for alternative interface metaphors will depend on user knowledge, comprehension, skills and performance for effective use of ICT systems.

This study did not find the widely used intention based individual level Technology Adoption Models (TAM) (Fishbein and Ajzen, 1975; Davis, 1989; Davis et al., 1992, Venkatesh and Davis, 2000; Venkatesh et al., 2003) directly suitable to establish factors that explain or predict user support for the use of ICT systems for the following two important reasons. Firstly, whilst user adoption of a technology might be related to user support for the technology, the main constructs of TAM such as perceived ease of use and perceived usefulness are technology dependent characteristics. These characteristics do not actually explain knowledge, experience, competence and skills of users in using technology. Secondly, researchers have agreed that there is a gap between intention and behaviour that remains to be understood or explained (Sheeran, 2002; Amireault et al., 2008; Bhattacherjee and Sanford, 2009; Kuo and Yen, 2009). In addressing the intention behaviour gap, it would be prudent to explore user characteristics such as competence to explain support for a technology. If a user is experienced in the use of one technology, there is likelihood that he/she might declare support for similar technology.

To further define the construct of user support for ICT, in a study by Dishaw and Strong (1990), where the integration of TAM was extended by Task-Technology Fit (TTF) model, it was found that tool functionality is directly related to perceived ease of use and attitude towards use. Following this path of reasoning, a combination of perceived usefulness and intention to use a tool could translate into actual tool use. In the proposed TSM, support is not only defined as the acceptance of the tool, but it also includes promoting the use of the tool. The study therefore had to determine whether the African village metaphors could improve tool functionality and perceived usefulness, which would influence attitude towards use. Even the integrated model proposed by Dishaw and Strong (1990), stopped short of promoting the use of the tool. The construct of support for the model proposed by this study therefore includes attitude towards the tool, intention to use, actual use of the tool and promoting the tool.

Miller's pyramid discriminates between four knowledge constructs and provides mechanisms for constructs assessment. At the lowest level of Miller's pyramid is the knowledge type called" know that" or simply knowledge, which is a formulation that is often used to describe knowledge of knowing things or reciting a relevant theory (Ferris, 2009). In the context of this study, it means the assessment of what the Africa rural users already know about village object metaphors. Forming the base of Miller's pyramid represents the foundation knowledge upon which competence is built. The assessment of knowledge should consist of questions that focus on principles of simply examining what a user knows about ICT systems. Miller's pyramid provides another knowledge type called "knows how" or comprehension. This knowledge type can be equated to the knowledge base required for effective functioning as ICT system users. Whilst this knowledge base is necessary, it is insufficient. Comprehension is Ryle's formulation to describe the capacity to perform a function. This capacity is distinct from the one to describe the area of knowledge related to the reciting of the relevant theory (Ferris, 2009). In the context of this study, it is the functional knowledge that emphasizes the capacity of African rural users to comprehend how to perform a function using ICT systems and not to articulate a description of what they know about the ICT system. This type of knowledge does not preclude one's skills to articulate what is known, but it only emphasizes the skills to perform an act. The distinctive feature of "know how" and "know that" knowledge types is that the knower's orientation is concerned with doing a function rather than describing something (Ferris, 2009).

The "shows how" or skills is Miller's knowledge assessment of how a user is able to integrate "knows that" and "know how" into a successful outcome with the ICT systems. Although users may "know that" and they may "know how", but they may not be able to integrate knowledge or skills into a successful outcome. The emphasis in skills is on the ability of the knower to choose and perform some actions in an appropriate and effective manner. The only test of skills is to set a practical test in which the candidate must perform the action. This knowledge type contrasts with comprehension, where the emphasis is on ability to perform an action, but skills are usually associated with some judgement foundation knowledge concerning such matters as when one would do the action or constraints or other factors impacting on the choice of whether or how to act (Ferris, 2009). In this particular simple case, African rural users should be able to associate similar village metaphors with the existing office metaphors. For instance, they should be able to relate an African basket metaphor to an office file to convey the meaning of file storage.

In a study by Abugabah et al. (2009), a consolidated model was presented to link information quality, system quality, user characteristics and task technology fit to evaluate the impacts of Information System (IS) through ease of system usage and usefulness on user‘s performance. The factors affecting user performance include system ease of use as influencing system quality and user experience as a user characteristic. Performance is therefore measured by the results of the actions of the end user. A previous study has found that performance impact relates to accomplishment of a portfolio of tasks by an individual. Higher performance implies certain mix of improved efficiency, improved effectiveness and higher quality (Goodhue and Thompson, 1995).

The highest level of Miller's pyramid is the knowledge type called "does", which focuses on methods that provide an assessment of routine performance. The knowledge type is the translation of skills into actions for the purpose of performance improvement, for example the actual use of an ICT system by African rural users to demonstrate how such a system improves performance in their daily business.

4.1.2 The Technology Support Model

This study develops and empirically validates the Technology Support Model (TSM) based upon human cognitive properties of knowledge, comprehension, skills, performance and support. The primary purpose of the model was to assess the support of users for technology such as interface object metaphors based on the user characteristics and not system characteristics. As a part of the study, user skills to associate alternative concrete metaphors with computer actions and the interaction effects of culture on the relationship between knowledge, comprehension, performance and support for alternative concrete metaphors were examined. In deciding to accept and use technology, the usefulness of the technology is weighed against the learning curve and fear of failing. Zajicek (2001) argues that some older adults fear learning sufficient skills to use the internet more efficiently and perceive this as a waste of time and energy. Zajicek (2001) investigated constructs that inhibit web access for older users and explored HCI design aspects that accommodate older adults with age related disabilities, such as memory, sight and cognitive impairments. The research showed that older adults are less able than young adults to retrace and navigate a route. Visual impairment plays a role in recognition of icons.

UNESCO (2008) has described the progression in ICT competence to reach the level of knowledge production as mastery of basic tools, complex tools and pervasive tools. Basic tools include the use of computers along with productivity enhancement software, web content and networks for management purposes. Complex tools include using open-ended technology tools to understand concepts, data analysis tools and simulations. Pervasive tools include a variety of networked devices, digital resources and electronic environments to create and support the community in its production of knowledge and anytime, anywhere collaborative learning. This means the competence level of users in using ICT systems at different levels will determine whether meaningful knowledge can be produced. Although Krauss (2009) supports the UNESCO framework, she cautions that researchers in rural African societies should focus on how it should be interpreted for the community, including emphasising collisions that may occur between underlying values and assumptions embedded in the policy framework and the realities faced by the communities. Some of these realities include extreme poverty, HIV and TB health problems and low literacy levels. Krauss (2009) recommends pre-basic computer literacy training where the computer is introduced as a tool because western culture is embedded in ICTs, which makes learning it extremely difficult for rural African cultures. This study tries to mediate by embedding mode of African culture into ICTs. As a result, knowledge, comprehension, skills and performance were selected as factors to investigate the support of African rural users for alternative concrete metaphors.

Central to this research was to establish the relationships between user knowledge, comprehension, skills, performance and support for alternative concrete metaphors. In addition, it was also central to this study to empirically establish the effects of culture on user support. The relationship between knowledge and skills has been found to exist and that knowledge positively correlated with cognitive skills (Chamorro-Premuzic et al., 2006). This relationship between knowledge and skills provides support for the original two-factor theory of intelligence and conceptualization of knowledge (Cattell, 1967; Cattell, 1987). Although existing theory such as Technological Pedagogical Content Knowledge (TPACK) (Mishra and Koehler, 2006) has established relationship between knowledge (there referred to as content knowledge), pedagogy skills (not consider in this work because pedagogy refers to different learning styles) and comprehension (there referred to as technology knowledge). In addition, the theory of Task-Technology Fit (TTF) posits that the degree of fit between tasks and technology will impact working performance outcomes and technology utilization (Goodhue & Thompson, 1995). The theory further portrays individual characteristics as a strong determinant of TTF. However, relationships between the constructs of knowledge, comprehension, skills, performance and support as well as the impact of the culture on relationships involving user support have not in general been studied.

In order to be more generic, this study posits that user competence is a strong determinant of user performance, which influences technology support. Competence is generally understood as qualities, motivation, self-definition, social role, attitude, knowledge and skills that are closely related to the people’s posts and their working performance and distinguish high achievers and ordinary workers (Xing et al. 2010). Figure 4.1 shows the TSM developed in this study to relate user competence and user performance to technology support. TSM is offered as a metamodel to define the general structure and relationships for family of models that conforms to the theory of TSM.

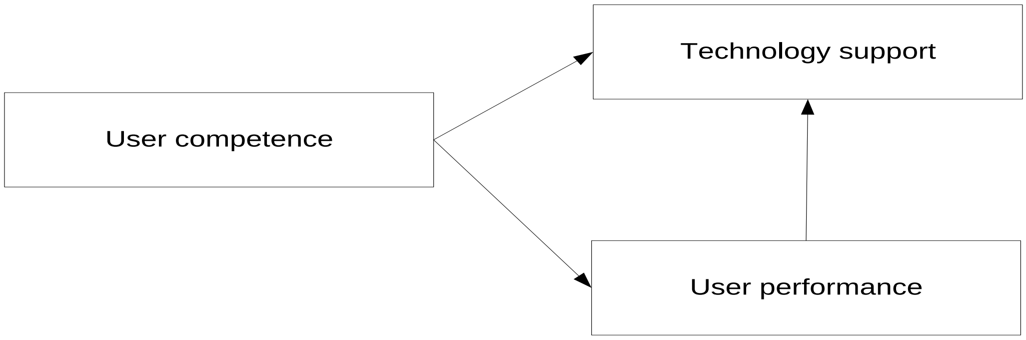


Figure 4.1: Technology support metamodel

In this study, competence is a user characteristic to connote knowledge, comprehension and skills. Figure 4.2 shows an instance of TSM metamodel to establish the relationships between the constructs of knowledge, comprehension, skills, performance and support for alternative concrete metaphors. The constructs of knowledge, comprehension and skills are instances of an abstract construct called user competence and relationships between these constructs are hypothesised.

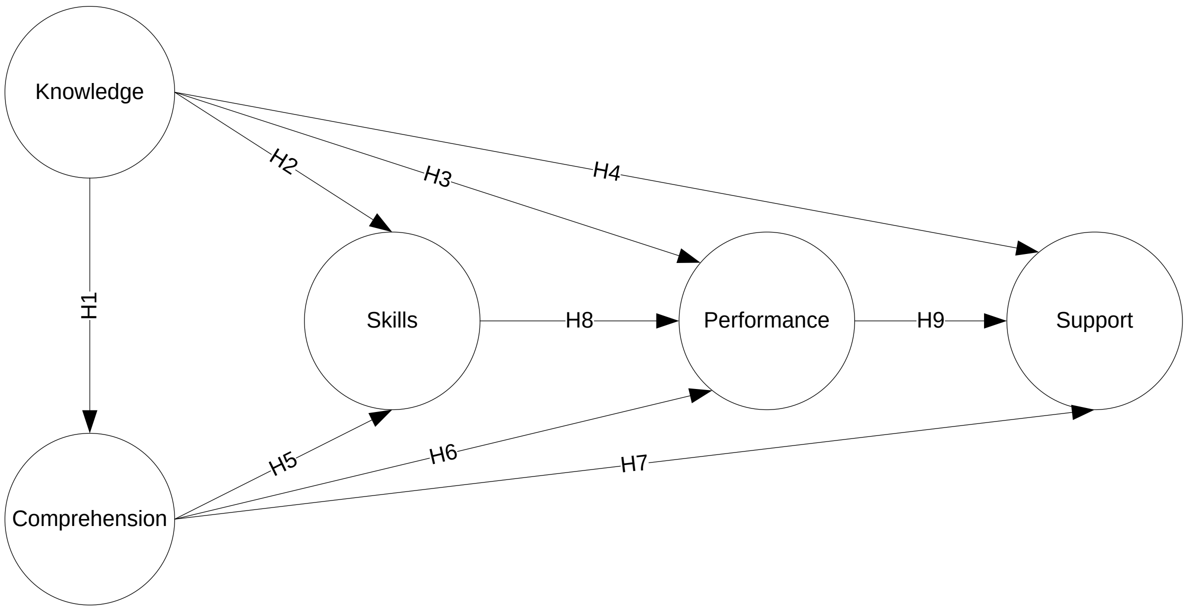


Figure 4.2: Instance of technology support metamodel

4.2 Research Hypothesis from the Research Model

This section describes research hypotheses that were constructed from the research model and techniques that were followed to test the hypotheses. Research hypotheses are theories or propositions whose outcomes can be empirically tested to be either true or false. They are predictions that are made by researchers about the expected relationships among a set of connected constructs. Research hypotheses are numerical estimations of population values based on the empirical data that were elicited from certain samples. The use of hypotheses is common in experiments where investigators compare groups or try to formally establish relationships among variables. This study develops a set of 14 hypotheses and selects Partial Least Square (PLS) approach to test the hypotheses. The experiments follow a statistical approach of setting up a set of hypotheses and then testing the hypotheses. The hypothesis testing was done using the bootstrapping method implemented in SmartPLSversion 2.0 (Ringel et al., 2005). A statistical significance test was used to analyse the results of the experiments designed in this study.

The general problem of hypothesis testing is to perform statistical significance test to claim that the difference was not observed due to chance. The statistical inference schemes are often used to test the validity or otherwise of the hypotheses. There are a number of bootstrap hypothesis tests, including t-test bootstrap (Sakai, 2007) and a procedural analysis called multiple comparisons, which is based on the analysis of variance (Hochberg and Tamhane, 1987). The approach adopted in this study is that of t-test bootstrap as it is more suitable for the purpose of this study. Usually, when a simple t-test bootstrap is used to establish the significance of a hypothesis, a significance alpha level that determines the cut-off value of the t-test bootstrap is specified. The purpose of the alpha cut-off is to ensure that when there is no real difference, it is possible to incorrectly find a significant difference no more than the cut-off value. The t-test statistics works effectively under the assumptions that the data to test are normally distributed and that they have equal variance. However, within the PLS framework, these requirements are not needed, thereby making the PLS approach more robust.

4.2.1 Direct Interaction Effect Hypothesis

A direct relationship exists between two variables A and B if a direct path goes from one of the variables to the other. However, if the path transcends through another variable C, the relationship is called indirect. Table 4.1 shows a set of direct interaction effects hypotheses constructed based on the TSM.

Table 4.1: Direct interaction hypothesis to test research

Hypothesis	Relationship
H1	User knowledge of user interface object metaphors will have an effect on the user comprehension of the metaphors.
H2	User knowledge of user interface object metaphors will have an effect on the user skills.
H3	User knowledge of user interface object metaphors will have an effect on the user performance using ICT systems.
H4	User knowledge of user interface object metaphors will have an effect on user support for the metaphors.
H5	User comprehension of user interface object metaphors will have an effect on the user skills.
H6	User comprehension of user interface object metaphors will have an effect on the user performance using ICT systems.
H7	User comprehension of user interface object metaphors will have an effect on user support for the village object metaphors.
H8	User skills on ICT application will have an effect on user performance using ICT systems.
H9	User performance using ICT systems will have an effect on user support for user interface object metaphors.

4.2.2 Moderating Interaction Effect Hypothesis

This study also examines culture moderating interaction effects on the relationship between the independent constructs of knowledge, comprehension, skills and the dependent construct of support. A moderator is a categorical factor such as gender, age, culture, experience and education that influences the strength or direction of a relationship between an independent and a dependent variable. Besides the examination of direct effects, researchers are interested in interaction effects to comprehend complex relationships among factors (Chin et al., 2003; Norton et al., 2004; Sun and Zhang, 2006; Henseler and Fassott, 2010). An investigation into interaction effects is valuable in intervention research to obtain information on the process by which an intervention achieves its effects (Chin et al., 2003; Henseler and Fassott, 2010). Following these lines of reasoning, Figure 4.3 shows three moderating interaction effects hypotheses that were tested in this study.

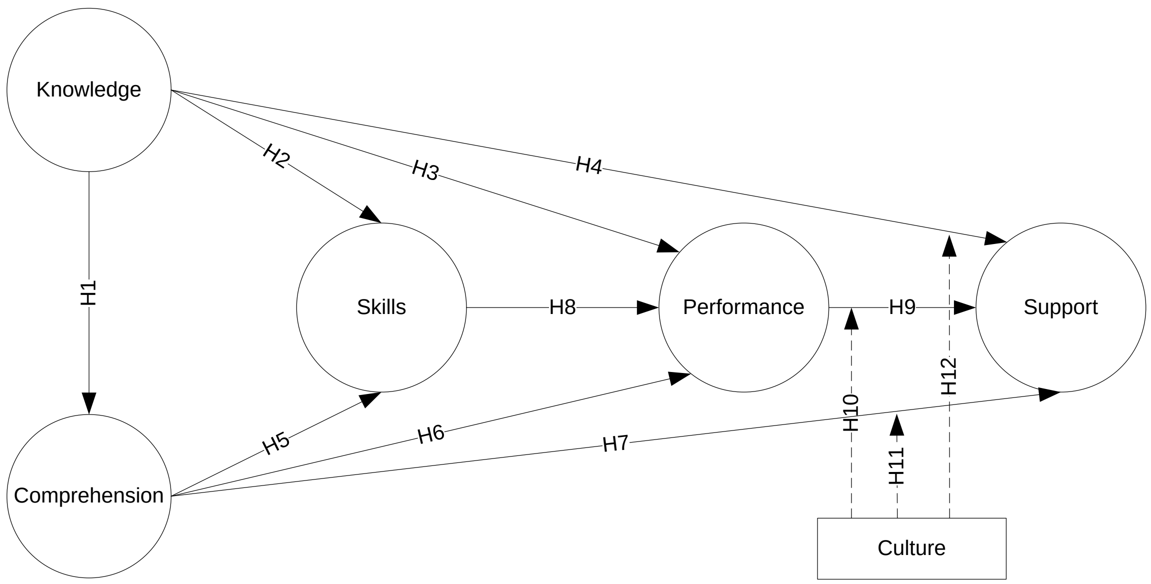


Figure 4.3 Technology support model with culture moderation effects

The possible interaction effects of culture on the relationship between user performance using ICT systems and user support for user interface metaphors have to be established. Consequently, the culture moderation interaction effects research hypotheses are:

Table 4.2: Culture moderator interaction effect hypothesis to test research

Hypothesis	Relationship
H10	Culture will moderate the effects of user knowledge of user interface object metaphors on user support for village object metaphors.
H11	Culture will moderate the effects of user comprehension of user interface object metaphors on user support for village object metaphors.
H12	Culture will moderate the effects of user performance using ICT systems on user support for village object metaphors.

4.2.3 Mediating Interaction Effect Hypothesis

This study, in addition to moderating interaction effects, examines mediation interaction effects of performance on the relationship between independent constructs of knowledge, comprehension and support. A mediator is a factor that explains the relationship between two other factors such that when the effect of the mediator is removed, the relationship no longer exists (Baron and Kenny, 1986; Chin et al., 2003; Henseler and Fassott, 2010). Mediation analysis is a research activity suggested to enhance the testing of behaviour theory to understand the underlying mechanism that brings about changes in dependent constructs (Noar and Mehrotra, 2011). Figure 4.4 shows two mediating interaction effect hypotheses that were tested in this study.

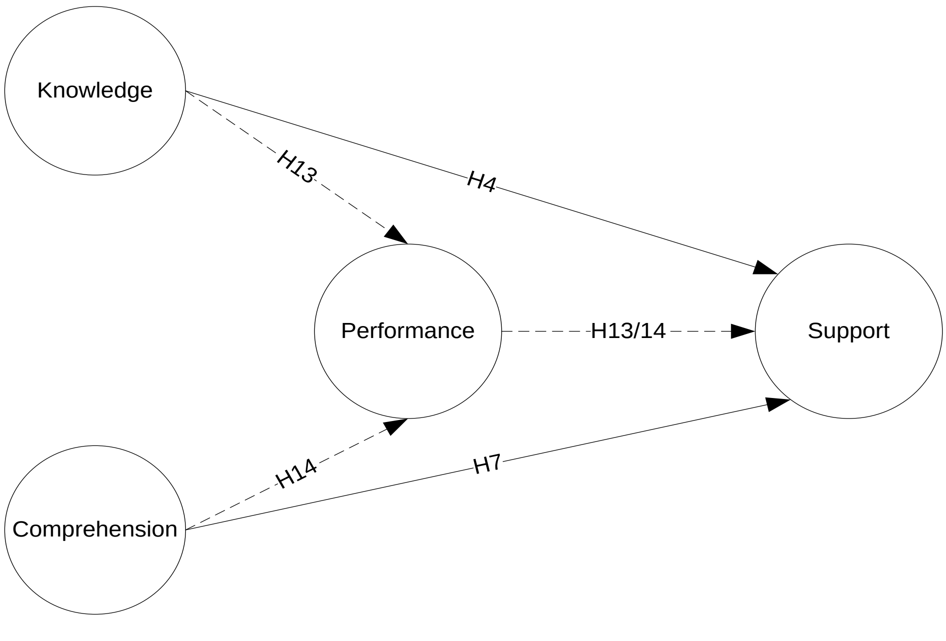


Figure 4.4: Technology support model with performance mediation effects

The interaction path from knowledge to support through performance has to be established to determine whether user performance using ICT systems is a mediator or the direct path from knowledge to support can be followed alone. As a result, the culture mediation interaction effects research hypotheses are:

Table 4.3: Performance mediation interaction effect hypothesis to test research

Hypothesis	Relationship
H13	User performance using ICT systems will mediate the relationship between user knowledge of user interface object metaphors and user support for alternative African village metaphors.
H14	User performance using ICT systems will mediate the relationship between user comprehension of user interface object metaphors and user support for the alternative African village metaphors.

4.3 Experimentation to Test Research Hypotheses

The purpose of the experiment was to intuitively determine those factors that influence support to use alternative African village metaphors as user interface objects. Furthermore, the experiment was designed to determine whether a basic knowledge of common African village objects and their traditional uses exists and whether these objects could be associated with computer actions. Lastly, the experiment aimed to empirically determine the effects of culture on user support for African village metaphors as alternative metaphors to the office metaphors.

It is important to emphasise that culture, race and ethnicity are often interchangeably used. However, each of these concepts is markedly different. As pointed out by Straub et al. (2002), the definition of culture has traditionally been difficult for Information Systems (IS) research. IS research nearly always assumes that an individual living in a particular place and time belongs to a single "culture". By this assumption therefore, those people living in South Africa, with its 11 official languages at this time have the same culture. Some definitions describe culture as a set of values, a set of outcomes, a set of beliefs or a way of being (Straub et al., 2002). Hofstede (1980) offer a mechanism whereby a cultural value can be assigned to a particular group of people. It needs to be pointed out that although a group of people could have similar values, but individuals within that group could have varying adherence to those values. The role that social norms, beliefs and roles play could influence the values of an individual. It would therefore be useful to focus on the pertinent values of a group that produce certain behaviour patterns. For example, Hofstede (1991) would “test on values that are more aligned with what takes place in the workplace”.

Race is often used to refer to national origin. As Betancourt and Lopez (1993) suggest, race is generally defined in terms of physical characteristics such as skin colour, facial features and hair types that are common to an inbred of a geographically isolated population. The research has not established a clear link between the biological aspects of race and behaviour. Betancourt and Lopez (1993) suggest that the role of specific cultural and social variables be clearly separated from that of biological and other variables. Ethnicity on the other hand is closely related to culture, which can be described as the way of life of people, including the externally constructed environment such as politically and environmentally. This also include the internalized rules, expectations and values that guide communications, thinking and behaviour, while ethnicity refers to the membership of a culturally defined group (Harkness et al. 2009). In this study, using Hofstede method to test for values that are pertinent to the workplace and belief, three groups were used to test for the research hypotheses. The first group consisted of participants belonging to the ethnic cultural group of black African for whom the African village objects should be familiar and form part of their culture. The second group consisted of White/Coloured participants and the third group consisted of Indian for whom the African village objects are not an integral part of their culture.

For the purpose of this research work, a small sample of 71 participants was selected from study group in the KwaZuluNatal province of South Africa. Table 4.4 shows the demographics of the participants, wherein more participants from Indian cultural group (49.30) took part in the exploratory study. The participants consisted of 38.03% males and 61.97% females. The ages of participants are ranging from 20 to 69 years with the average age of 34.22 years and standard deviation of 7.82 years. The largest age group was among 20 – 29 years (40.85%) and no participants between the age group of 60-69. There were four choices for the user interface experiences of participants, those with experience in at least one of computer, ATM and cell phone) and those with no experience in any of these system interfaces. More participants are familiar with user interface of ATM plus any other system user interface (52.11%) and less number of participants is familiar with computer user interface plus any other user interface (18.31). Those who are not familiar with any user interface constitute 25.35% and those that are familiar with at least one user interface system constitute 74.65%. This result implies that more participants are familiar with the concept of user interface.

Table 4.4: Demographics of participants, N=71

Characteristic	Content	Occurrence	Percentage (%)
Cultural group	Black African	30	42.25
	White/Coloured	6	8.45
	Indian	35	49.30
Age group	20-29	29	40.85
	30-39	20	28.17
	40-49	17	23.94
	50-59	5	7.04
	60-69	0	0
Gender	Male	27	38.03
	Female	44	61.97
User interface experience	Not used computer, ATM or cell phone	18	25.35
	Used computer	13	18.31
	Used ATM	37	52.11
	Used cell phone	44	61.97

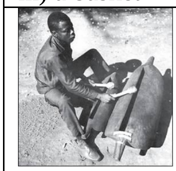
This research is aimed at assessing user performance and user support for some African cultural objects to be associated with computer actions and used as icons. The first task was to assess the knowledge of African users with African concrete metaphors. Current computer interface icons are usually designed based on the desktop metaphor, which assumes that people use computers in a work and office environment seated behind a desk. These people are therefore supposed to be familiar with office objects such as scissors, envelopes, folders, files and clipboards whose recognition level is naturally expected to stay high when translated into icons for computer interfaces. The first aim of the survey was therefore to determine whether the icons based on current office metaphor are as easily recognizable as generally thought. In doing so, a sample of icons found commonly in office applications such as word processing and spread sheets were tested to determine whether participants could identify their functions. Participants were asked to identify from a list of computer actions presented, the action associated with a given icon. The participants were awarded a score of 1 for obtaining the correct identification and a score of 0 for incorrect identification.

In this study, sets of questions were designed to assess the acculturation knowledge and visual processing cognitive skills of participants. The Miller pyramid (1990) specifies a set of tools to access individual knowledge types. Following is the description of how the constructs of the TSM developed in this study were measured.

4.3.1 Measuring User Knowledge

Multiple choice questions were used to measure the knowledge of participants on African village object metaphors (Heukelman and Eyono Obono, 2009). The purpose of the assessment was to find out whether rural African users would be able to correctly name each visual object metaphor presented to them during the experimentation. A score of 1 is allocated to a participant for each object metaphor correctly named and a score of 0 is allocated otherwise. In all, five village object metaphors were presented to the users for naming. The images of these items commonly found in African villages were presented to participants. Table 4.5 shows the list of village objects presented to the users for identification.

Table 4.5: Manifest items for measuring user knowledge

		
KN1. Name the above object		
a) a pumpkin d) a pounding tool g) a chair j) a stone m) a basket	b) a calabash e) drums h) a kola nut k) a box n) I don't know	c) a bowl for water f) a foot rest i) a loaf of bread l) a pot
		
KN2. Name the above object		
a) a pumpkin d) a pounding tool g) a chair j) a stone m) a basket	b) a calabash e) drums h) a kola nut k) a box n) I don't know	c) a bowl for water f) a foot rest i) a loaf of bread l) a pot
		
KN3. Name the above object		
a) a pumpkin d) a pounding tool	b) a calabash e) drums	c) a bowl for water f) a foot rest

g) a chair j) a stone m) a basket	h) a kola nut k) a box n) I don’t know	i) a loaf of bread l) a pot
		
KN4. Name the above object		
a) a pumpkin d) a pounding tool g) a chair j) a stone m) a basket	b) a calabash e) drums h) a kola nut k) a box n) I don’t know	c) a bowl for water f) a foot rest i) a loaf of bread l) a pot
		
KN5. Name the above object		
a) a pumpkin d) a pounding tool g) a chair j) a stone m) a basket	b) a calabash e) drums h) a kola nut k) a box n) I don’t know	c) a bowl for water f) a foot rest i) a loaf of bread l) a pot

4.3.2 Measuring User Comprehension

The multiple choice questions were used to measure the understanding of participants of the traditional use of the African village object metaphors. The purpose of the assessment was to find out whether rural African users would be able to correctly identify the use of each visual object metaphor that was presented. A score of 1 is allocated to a participant for each object metaphor that was correctly identified and a score of 0 is allocated otherwise. In all, five village object metaphors were presented to the users for the purpose of using them to perform actions. Table 4.6 shows the list of village objects presented to the users for performing actions.

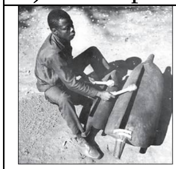
Table 4.6: Manifest items for measuring user comprehension

	
CM1. What can you use the above object to do?	
a) To use as eating utensil c) To sort grain e) To send a message g) To use as a punching bag i) To share by eating together with others	b) to keep fluid such as beer or wine d) To pound foodstuff f) To use for decoration h) To sit on j) To hold the roof down

k) To keep things for a medium/long period	l) I don’t know

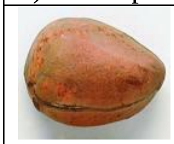
CM2. What can you use the above object to do?

a) To use as eating utensil	b) to keep fluid such as beer or wine
c) To sort grain	d) To pound foodstuff
e) To send a message	f) To use for decoration
g) To use as a punching bag	h) To sit on
i) To share by eating together with others	j) To hold the roof down
k) To keep things for a medium/long period	l) I don’t know



CM3. What can you use the above object to do?

a) To use as eating utensil	b) to keep fluid such as beer or wine
c) To sort grain	d) To pound foodstuff
e) To send a message	f) To use for decoration
g) To use as a punching bag	h) To sit on
i) To share by eating together with others	j) To hold the roof down
k) To keep things for a medium/long period	l) I don’t know



CM4. What can you use the above object to do?

a) To use as eating utensil	b) to keep fluid such as beer or wine
c) To sort grain	d) To pound foodstuff
e) To send a message	f) To use for decoration
g) To use as a punching bag	h) To sit on
i) To share by eating together with others	j) To hold the roof down
k) To keep things for a medium/long period	l) I don’t know

CM5. What can you use the above object to do?

a) To use as eating utensil	b) to keep fluid such as beer or wine
c) To sort grain	d) To pound foodstuff
e) To send a message	f) To use for decoration
g) To use as a punching bag	h) To sit on
i) To share by eating together with others	j) To hold the roof down
k) To keep things for a medium/long period	l) I don’t know

4.3.3 Measuring User Skills

The skill-based exercises were used to measure the skills of participants in determining their ability to associate African village object metaphors with computer actions. The purpose of the assessment was to discover the extent to which rural African users would be able to correctly associate each visual object metaphor that was presented to them during the experimentation. A score of 1 is allocated to a participant for each African object metaphor that was correctly associated with a computer action and a score of 0 is allocated otherwise.

In order to guide the users in their sense of judgement, it was necessary to first assess their knowledge of current office metaphors. As a result, the first of the skills based exercise was for the users to correctly identify five office icons that were presented for identification. As a result, the first part of the assessment was a kind of pre-mock to answer multiple choice questions, which assess their knowledge of office icons. The intention of the pre-mock exercise was to examine how the knowledge of office icons and knowledge of village objects impact on the ability of rural users to associate village objects with computer actions. Figure 4.5 shows the possible relationship between knowledge of village objects and knowledge of office icons with user skills.

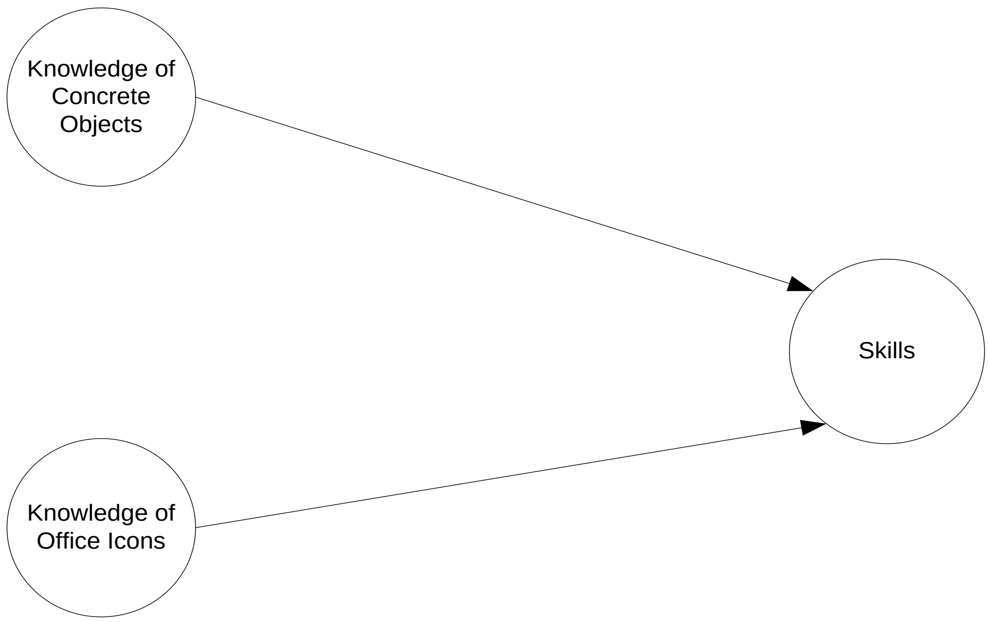
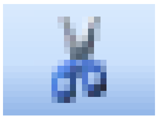
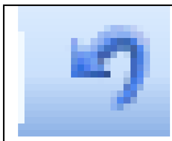
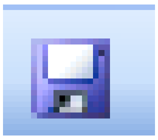


Figure 4.5: Relationships between knowledge of village objects, knowledge of office icons and skills

Table 4.7 shows the list of office objects presented to the participants in a pre-mock exercise to guide their sense of judgement.

Table 4.7: Manifest items for measuring user knowledge of office icons

ICON	Possible Computer Actions
OK1. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
OK2. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
OK3 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
OK4.	a) To save work permanently (on disk)

	b) To save work for a short period (into primary memory c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don’t know
OK5. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don’t know

The second aim of the skill-based exercise was to establish the extent to which African rural users will be able to associate African village objects with computer actions. The purpose was to determine whether a selection of objects generally found in African villages could be used as alternative to office icons and therefore form the basis of an African village metaphor for user interfaces. It was therefore, important to determine whether those African village objects could be associated with computer actions, depending on the traditional use of the object. Table 4.8 shows the list of 5 icons to illustrate the way that the skill-based exercise was conducted during the experimentation. Participants were asked to circle the computer action in the “Possible Computer Actions” column that is most suited to the action.

Table 4.8: Manifest items for measuring user skills

Village Metaphor	Possible Computer Actions
SK1. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
SK2. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
SK3. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
SK4.	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file

	g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know
SK5. 	a) To save work permanently (on disk) b) To save work for a short period (into primary memory) c) To create a new file d) To share files with others e) To undo the last action f) To open a file g) To close a file h) To copy a section i) To go to a new page j) To display a file k) To paste saved content l) To indicate work in progress m) To send a message n) I don't know

4.3.4 Measuring User Performance

The performance assessment questions were used to assess the performance of participants using ICT to improve their local businesses. The purpose of the assessment was to discover whether rural African users were able to apply ICT to improve user performance. The performance of ICT for individual users is therefore measured in terms of whether support translates into use. A score of 1 is allocated to a participant for each agreement with the question asked and a score of 0 is allocated otherwise. Table 4.9 shows the list of office objects presented to the users for identification.

Table 4.9: Manifest items for measuring user performance

Item	No	Yes
PM1. I apply ICT to establish a relationship with new business customers.		
PM2. I apply ICT to improve communication with business customers.		
PM3. I apply ICT for record keeping and product documentation.		
PM4. I apply ICT for the purpose of advertising my products.		
PM5. I apply ICT to enhance business effectiveness and efficiency.		

4.3.5 Measuring User Support

Five Boolean Likert scale questions were used to assess the support of participants for alternative African village object metaphors. The purpose of the assessment was to discover whether rural African users would declare support for African village object metaphors as alternative icons for a user interface. A score of 1 is allocated to a participant for each African object metaphor supported in a yes response and a score of 0 is allocated otherwise. Table 4.10 shows the list of questions presented to the participants to assess their support for alternative African village object metaphors.

Table 4.10: Manifest items for measuring user support

Item	No	Yes
SP1. I support using African cultural objects as alternative icons to make user interface more acceptable to me.		
SP2. I support creating new icons using an African village theme to help me when learning user interfaces.		
SP3. I support using an African village theme as alternative icons to make user interface easier to understand for novice African users		
SP4. I support a selection of themes closer to my own culture from the icons list.		
SP5. I support replacing all the icons with the African village theme icons.		

Chapter 5 Data Analysis Method

This chapter presents the Partial Least Square (PLS) data analysis method to establish relationships between constructs of the research model. The PLS method is especially useful in an exploratory study. In this particular study, the focus is on ways in which user characteristics such as knowledge, comprehension, skill and performance influence user support for technology. The study seeks to explore the validity of a set of initial hypotheses on the basis of the empirical data collected. This concerns the structure of the research model constructs and the relationships between those constructs that are paths representing direct effects. The analysis is characterized as a set of model analyses that is guided by theoretical considerations and empirical evidence.

This study conducts an empirical analysis to investigate how the magnitude of the relationship between the constructs of TSM differs with respect to the cultural background of participants who were studied. The analysis method is based on the empirical data obtained by surveying 71 participants to assess their knowledge, comprehension, skills, performance and support for alternative African village metaphors. The empirical data obtained was analysed by running PLS algorithm and performing the necessary calculations to establish relationships between hypothesized constructs of TSM. The outcomes of the relationships are significance of the relationships, reliability, validity and predictive capability of the research model. The practical implication of the study is to help system developers to better understand important issues that must be taken into cognisance when developing ICT systems for rural users. However, before the analysis outcomes can be presented, it is essential to understand the basic elements of the PLS analytical modelling method. The following sections provide succinct background information on PLS method so that a reader can have good understanding of the way the research data are analysed.

5.1 The Partial Least Square Method

This study applies the Partial Least Square (PLS) (Wold, 1966) analytical modelling method to empirically establish relationships between constructs of TSM and to ultimately solve the research questions raised. Examples of different methods available in the literature for analysing relationships between constructs are Principal Components Analysis (PCA), Multiple Regression Analysis (MRA), Factor Analysis (FA), Multiple Factor Analysis (MFA), Path Analysis (PA) and Structural Equation Modelling (SEM). Each of these methods has its own requirements, merits and demerits. PLS generalizes and combines features from PCA and MRA to predict a set of dependent variables from a large set of independent variables. PLS regression is related to canonical correlation and multiple factor analysis (Escofier and Pages, 1988; Tenenhaus, 1998; Pages and Tenenhaus, 2001). The distinctive characteristic of PLS when compared to other models, is that it preserves the asymmetry of the relationship between predictors and dependent variables, but other techniques treat them symmetrically.

The PLS is robust against statistical violations of normality, independent observations, co-linearity, noise, small sample sizes, outliers and independent of measurements distribution (Chin et al., 2003; Goodhue et al., 2006; Aibinu and Al-Lawati, 2010; Rigdon et al., 2010). PLS uses the ordinary Least Squares Regression (LSR) steps in the calculation of loadings, scores and regression coefficients (Griep et al., 1995). PLS regression extends Multiple Linear Regressions (MLR) without imposing the kind of restrictions imposed by many other multivariate extensions of MLR models such as discriminant analysis, principal components regression and canonical correlation. This flexibility of PLS allows it to be widely used in situations where the use of traditional multivariate methods is severely limited. For instance, when there are fewer observations than predictors. In addition, PLS regression can be used as an exploratory analysis tool to select suitable predictors and to identify outliers before classical linear regression. PLS regression has been applied in various disciplines including computational chemistry (Geladi and Kowalski, 1986), sensory evaluation (Martens and Naes, 1989), neuroimaging (Mcintosh et al., 1996), consumer and service research (Ringle et al., 2010). Appendix A gives tutorial on step by step procedures involve in the application of PLS.

5.2 The Partial Least Square Path Modelling

The PLS path modelling is a general method for estimating the causal relationships that exist in path models, which involve latent constructs that are indirectly measured by various items. Previous studies have provided the methodological foundations and techniques for evaluating the results of path models (Tenenhaus et al., 2005; Henseler et al., 2009). PLS path modelling has several advantages especially for small data size, non-normally distributed data, for non-convergent and complex models with many parameters (Fornel and Bookstein, 1982). The use of PLS path modelling is predominantly found in the fields of social science, marketing, strategic management and management information systems, but rarely used in HCI studies.

The basic ideal of path modelling is to model the relationship between Manifest Variables (MVs) and latent variables (LVs) using the PLS method. The PLS models are generally defined by two sets of linear system of equations called the outer model and the inner model. A PLS path model is described by two models (Chatelin et al., 2002):

a) A measurement model, also called outer model, which relates the MVs to their own LVs. The outer model takes into cognisance the relationships between each LV and the corresponding MVs.
b) A structural model, also called inner model, which relates certain endogenous LVs to other LVs in the model. A LV that is a dependent variable is called endogenous and exogenous if it is an independent variable. The inner model takes into cognisance the relationships among LVs.

5.2.1 The Outer Model

The outer model specifies the relationships between LVs and their associated observed or MVs. The three ways to relate the MVs to their LVs are reflective, formative and MIMIC (multiple effect indicators for multiple causes). The standardized loadings are often recommended for interpretation as they represent the correlation between MV and corresponding LV (Vinzi et al., 2010).

5.2.2 The Inner Model

The inner model defines a linear system of equations that relate the causal links between unobserved or LVs. These structural equations can be estimated by individual Ordinary Least Square (OLS) multiple regressions where the LVs are replaced by their estimates. However, the use of OLS multiple regressions may be disturbed by the presence of strong multi co-linearity between the estimated LVs. Consequently, PLS regression may be applied instead OLS (Tenenhaus et al., 2005).

5.3 Bootstrapping Method

A bootstrap procedure was implemented to assess whether the eigenvalue structure of the research model is significant or it is as a result of sampling fluctuations (Vinzi et al., 2010). The nonparametric bootstrapping (Efron and Tibshirani, 1993; Davison and Hinkley, 2003; Henseler et al., 2009) procedure was used in PLS path modelling to provide confidence intervals for all parameter estimates and building the basis for statistical inference. In general, bootstrap method provides an estimate of the shape, spread and bias of the sampling distribution of a specific statistic (Henseler et al., 2009). Bootstrapping treats the observed sample as if it represents the population. The procedure creates a large pre-specified number of bootstrap samples, for example 5000. The default value in SmartPLS is 100, but a higher number such as 200 may lead to more reasonable standard error estimates (Tenenhaus et al., 2005). Each bootstrap sample should have the same number of cases as the original sample. Bootstrap samples are created by randomly drawing cases with replacement from the original sample and PLS estimates the path model for each bootstrap sample. The obtained path model coefficients form a bootstrap distribution, which can be viewed as an approximation of the sampling distribution (Henseler et al., 2009).

5.4 Model Validity

A path model can be validated at three essential levels, which are quality of the outer model, quality of the inner model and each structural regression equation (Tenenhaus et al., 2005). Model validity tells whether a measuring instrument measures what it is supposed to measure in the context in which it is applied (Fornell and Larcker, 1981; Henseler et al., 2009; Pahnila and Warsta 2010; Raykov, 2011). Model validity can be measured by the estimate of convergent validity and discriminate validity of model factors. Convergent validity is the extent to which items of a factor represent the same factor (Fornell and Larcker, 1981). Convergent validity is measured by Average Variance Expected (AVE), which is the amount of variance that a factor captures from its measurement items and is calculated from the outer loading of an item (Henseler et al., 2009). Discriminate validity indicates the extent to which a given factor differs from other factors (Pahnila and Warsta, 2010). Discriminate validity is measured by calculating the Pearson product moment correlation between all pairs of factors (Spiegel, 1972).

The quality of outer model is measured by means of Communality Index (CoI), which measures how much of the MVs variability is explained by own LV scores. The mean communality is the average of all the squared correlations between each MV and the corresponding LV scores in the model. The mean redundancy for all endogenous blocks can be computed by averaging of all redundancy indexes. The coefficient of determination (R^2) of an endogenous block is the criterion often used to assess the predictive power of the inner model. R^2 is the amount of variance in a dependent factor that is explained by the research model (Cornell and Berger, 1987). There is another measure of the quality of the inner model, which is calculated through predictive relevance Q^2. The predictive relevance of an inner model represents a measure of how well the observed values are reconstructed by the model and its parameter estimates. If $Q^2 > 0$, the model has predictive relevance, otherwise the model represents a lack of predictive relevance (Chin, 1998; Ringle et al., 2010). The value of Q^2 is calculated in terms of the ratio of sum of the squared prediction error to sum of squares of observations.

In the case where the research model has more than one endogenous construct the overall predictive power of the model is accessed through the Goodness of Fit (GoF) index (Tenenhaus et al., 2004; Tenenhaus et al., 2005). The GoF index is a global criterion calculated as the geometric mean of the average CoI and the average R^2 value (Chin, 2010). The purpose of GoF index is to account for the performance of PLS model at both outer and inner models with a focus on overall predictive performance.

5.5 Interaction Effects

This study examines the interaction effects among factors of the TSM research model. Interaction effects represent the combined effects of factors on the endogenous measure. The interaction between factors measure whether the effect of one factor significantly depends in some way on the level of one or more factors. Researchers are interested in studying interaction effects to understand those issues which remain to be understood or explained and have always been topics of research interest (Sheeran, 2002; Michie and Nelson, 2006; Ma and Yuen, 2006; Haseloff and Ghadially, 2007; Jarrin et al., 2008; Li et al., 2008; Amireault et al., 2008; Bhattacherjee and Sanford, 2009; Hwang, 2009). Moreover, the complexity of hypothesized relationships has steadily increased. Besides the examination of direct effects, researchers are interested in interaction effects to understand complex relationships among factors (Chin et al., 2003; Norton et al., 2004; Sun and Zhang, 2006; Henseler and Fassott, 2010). There are two main types of interaction effects that can be measured in a research model, mediating effects and moderating effects. A mediator is a factor that explains the relationship between two other factors such that when the effect of the mediator is removed, the relationship no longer exists (Baron and Kenny, 1986; Chin et al., 2003, Henseler and Fassott, 2010). Mediation analysis is a research activity suggested to enhance the testing of theories or hypotheses to understand the underlying mechanism that brings about changes in dependent factors (Noar and Mehrotra, 2011). A moderator is a categorical factor such as gender, age, experience, culture and education that influences the strength or direction of a relationship between an independent and a dependent factor.

The test for moderating effect can be assessed by determining its strength or effect size and then testing for its significance (Helm et al., 2010). The effect size is considered large, medium and small if greater than 0.35, 0.15 and 0.02 respectively (Cohen, 1988). The significance of the effect size is tested using the F-test as (Aibinu and Al-Lawati, 2010). The test for significance of a mediating effect induced by a factor F3 on the relationship between two factors F1 and F2 is based on the path coefficients of indirect relationships from F1 to F3 and F3 to F2 (Sobel, 1982). The mediation effect size can be estimated using the Variance Accounted For (VAF) that represents the ratio of interaction effect to main effect (Helm et al., 2010).

5.6 Paths Comparison

It is not possible to compare groups in PLS by using a global criterion. However, there is a possibility to compare the path coefficients between two groups at a time, which allows an interpretation of the differences in effects between groups (Eberl, 2010). In the context of this study, the difference in the impact of concrete and office knowledge on user skills can be revealed by comparing the resulting path estimators. The approach defined by Chin (2000) uses the re-sampling estimates for the standard errors of the structural paths in two paths under consideration gained from the bootstrapping procedure usually used for model evaluation (Chin, 1998; Eberl, 2010). The difference between the estimators of path models is tested for significance with a t-test (Chin, 2000).

5.7 Path Model Segmentation

The application of Structural Equation Modelling (SEM) for path modelling is generally based on the assumption that analysed data come from a single, homogeneous population, so that a unique global model well represents all the observations. However, in many practical applications, this assumption is unrealistic (Rigdon *et al*. 2010). It was generally shown that global data analysis can seriously be misleading when there are significant differences between segment specific parameter estimates (Hahn *et al*. 2002). The aggregation of data across diverse respondents can produce misleading results because of unobserved data heterogeneity, which typically do not feature a single homogenous population (Becker et al., 2009). As a result, the assumption that empirical data come from a single homogeneous population cannot be followed. This study is therefore not exempted from this problem, hence the application of Finite Mixture Partial Least Squares (FIMIX-PLS) segmentation algorithm to uncover heterogeneity in the TSM empirical data.

There are several methods available for PLS-based segmentation and examples include decision tree structure (PATHMOX), distance measure based PLS typological path modelling (PLS-TPM), response based detection of segments in PLS (REBUS), Fuzzy PLS path modelling for latent classification detection (FPLS-LCD), PLS genetic algorithm segmentation (PLS-GAS), PLS Finite Mixture (FIMIX-PLS) and PLS prediction oriented segmentation (PLS-POS) (Sarstedt, 2008; Becker et al., 2009). This study applies the FIMIX-PLS segmentation method (Ringle, 2006; Ringle et al., 2008) to detect and treat unobserved heterogeneity in the TSM empirical data. This segmentation method combines strengths of PLS with benefits of classifying data segments according to a statistical finite mixture of models (McLachlan and Basford, 1988) and an expectation maximization algorithm (Mclachlan and Krishnan, 1997). Accordingly, the method estimates model parameters and ensures the heterogeneity of data structure within a PLS path modelling (Sarstedt and Ringle, 2010).

The application of FIMIX-PLS follows the following four important steps. a) Standard PLS algorithm is applied to global data to obtain latent factors scores for each observation. The application of the standard PLS to global data is covered in confirmatory factor analysis and discriminate validity test. b) FIMIX-PLS algorithm is executed with user-specified number of segments and outcomes are compared to determine the number of segments to retain from dataset. The FIMIX-PLS was repeatedly applied to data sample using consecutive number of segments (Ringle *et al*. 2005). Hahn *et al*. (2002) proposed K=1, 2, 3, ... 10 number of segments. In this work, FIMIX-PLS was experimented with K=2, K=3, any further increase in the number of segments resulted in very small segments for meaningful interpretation. c) An analysis is performed to identify the factor that characterizes the uncovered data segment. An analysis of each segment is performed using demographic factors or factor items. d) Each segment is analysed separately by applying standard PLS algorithm to calculate local models whose parameters can be compared by means of PLS multi-group comparison procedures (Sarstedt and Ringle 2010). Segments were compared in terms of GoF, R^2 and path coefficient measures, which were determined after segment specific path model estimation were tested for validity and reliability.

In order to determine the correct number of segments to retain from data sample, segment specific outcome results are compared using various evaluation criteria. The most widely used criteria are Akaike Information Criterion (AIC) (Akaike 1973; Bozdogan 1994), Bayes Information Criterion (BIC) (Schwarz 1978), Consistent AIC (CAIC) (Bozdogan 1987) and Normed Entropy statistic (EN) (Ramaswamy *et al*. 1993). This work applies EN, which is an important criterion for analysing whether segment specific FIMIX-PLS result produces well separated clusters (Sarstedt et al., 2009; Sarstedt and Ringle 2010). EN indicates degree of all classified observations and heir estimated segment membership probabilities (Ringle *et al*. 2005). It ranges between 0 and 1, wherein a higher value corresponds to a better segment separation. The more the observations exhibit high membership probabilities for example higher than 0.7, the better they uniquely belong to a specific segment and can be properly classified using high EN values. The values of EN above 0.5 result in probability estimates that permit fuzzy segmentation (Sarstedt et al., 2009; Sarstedt and Ringle, 2010).

Chapter 6 Experimental Results and Discussion

This chapter presents the experimental results of the explorative research conducted in this study. The chapter also presents discussion of results and illustration of how the research questions raised were solved. This chapter is for the sake of lucidity, organized into two main sections of empirical results and discussion.

6.1 Empirical Results

The empirical results of this study are presented under the sub headings of outer model measurement, inner model measurement and heterogeneity measurement. The data analysis method discussed in Chapter 5 forms the foundation upon which scientific results are obtained in this study.

6.1.1 The Outer Model Measurement

The internal consistency of TSM was obtained using the Cronbach's alpha and the overall reliability of the model was tested using the Dillon-Goldstein's rho composite reliability metrics respectively. Table 6.1 shows the result of the reliability test, wherein it can be seen that composite reliabilities of all factors exceeded the required minimum of 0.70 (Pahnila and Warsta, 2010) with the lowest value being 0.72 for the skills factor. In addition, the internal consistency should exceed the value of 0.5 (Bhattacherjee and Sanford, 2009), which failed for the comprehension factor and passed for the remaining factors. However, this particular situation was not considered critical because internal consistency gives the estimate of lower bound for reliability and composite reliability gives an estimate of upper bound for reliability. The result was therefore accepted for the comprehension factor because the composite reliability exceeds the normal requirement. Moreover, the low value of internal consistency creates an impression of heterogeneity in the sampled data and this will be dealt with later in the heterogeneity measurement section.

Table 6.1: Reliability test

	Model construct				
Metric	Knowledge	Performance	Skills	Support	Comprehension
Internal consistency	0.63	0.72	0.55	0.77	0.44
Composite reliability	0.80	0.84	0.82	0.85	0.72

The validity of TSM was measured using convergent validity and discriminate validity metrics. However, the result of Confirmatory Factor Analysis (CFA) is first presented. The purpose of using CFA is to improve on convergent validity. In order to achieve efficiency, item loading were computed by means of a bootstrapping procedure with a 500 resample of construct level sign changes and number of cases equal to the original sample size. This was done for all three PLS weighting schemes (centroid weighting (Wold, 1973), factorial weighting (Lohmoller, 1987) and path weighting (Vincenzo et al., 2002). Table 6.2 shows this result, wherein it can be seen that there is no great differences between all schemes and among all the measures, item loading are significant at 0.01 and lie well above the suggested threshold of 0.5 in almost all cases. In this result, the manifest items such as CM1 and CM2 with low loadings less than 0.5 were dropped as they demonstrate a low correlation for the constructs they are supposed to measure. Hence, they make insignificant contribution to the validity result.

Table 6.2: Confirmatory factor analysis

				Centroid weighting		Factor weighting		Path weighting	
Constrcut	Items	Item Mean	Item Stdev	Item loading	T Statistics	Item loading	T Statistics	Item loading	T Statistics
Comprehension	CM3	0.28	0.45	0.63	4.01	0.67	4.83	0.66	4.53
	CM4	0.52	0.50	0.65	4.83	0.65	5.71	0.65	5.75
	CM5	0.48	0.50	0.73	6.50	0.69	6.11	0.70	6.83
Knowledge	KN2	0.83	0.38	0.70	6.53	0.68	6.04	0.69	5.68
	KN3	0.61	0.49	0.73	5.96	0.73	5.89	0.73	5.35
	KN4	0.75	0.44	0.80	8.82	0.81	11.05	0.81	11.66
Performance	PM1	0.96	0.20	0.74	3.99	0.75	4.61	0.74	4.32
	PM2	0.90	0.30	0.82	7.02	0.81	7.96	0.83	9.42
	PM4	0.90	0.30	0.74	4.54	0.76	4.77	0.74	4.18
Skills	SK3	0.35	0.48	0.83	12.80	0.84	17.56	0.84	15.27
	SK5	0.35	0.48	0.82	12.11	0.82	13.22	0.82	12.80
Support	SP1	0.73	0.45	0.88	17.16	0.86	9.95	0.88	11.56
	SP2	0.72	0.45	0.85	13.68	0.81	7.76	0.85	9.48
	SP4	0.56	0.50	0.71	8.22	0.73	5.57	0.70	7.22
	SP5	0.92	0.28	0.56	3.84	0.56	3.29	0.59	4.45
Average				0.75	8.00	0.74	7.62	0.75	7.90

The convergent validity of scale items was determined as AVE and tested using the following three important criteria. a) All item factor loadings should be significant and exceed 0.50 (Hair et al., 2006; Pahnila and Warsta, 2010). b) Composite reliability for each factor should exceed 0.70 (Pahnila and Warsta, 2010). c) Average Variance Extracted (AVE) for each factor should exceed 0.50 (Fornell and Larcker, 1981; Bhattacherjee and Sanford, 2009; Pahnila and Warsta, 2010).

The discriminate validity was determined as inter-construct correlation and systematically established using the following two important criterions. a) The square root of AVE for each factor should exceed the correlations between all other factors (Fornell and Larckers, 1981; Bhattacherjee and Sanford, 2009; Pahnila and Warsta, 2010). b) The loadings of each item is expected to be greater than all of its cross loadings (Chin, 1998; Henseler et al., 2009).

Table 6.3 shows the result of convergent validity and discriminate validity, wherein it can be seen that the highest correlation between any pair of constructs in the CFA model, was 0.75 for user comprehension and support factors. This value was however higher than the lowest square root of AVE among all factors, which was 0.68 for the user comprehension factor. Furthermore, the smallest AVE value among all factors in the CFA model was 0.47 for comprehension, which was lower than the desired minimum of 0.50. However, this particular instance was not considered critical as all items met the minimum item loading criterion of 0.5 (Hair et al., 2006; Pahnila and Warsta, 2010). The discriminate validity criterion was met for the data sample.

Table 6.3: Scale properties

Construct/Metric	Discriminate validity (inter-construct correlation)				
	Knowledge	Performance	Skills	Support	Comprehension
Knowledge	1.00				
Performance	0.26	1.00			
Skills	0.42	-0.06	1.00		
Support	-0.03	0.33	0.18	1.00	
Comprehension	0.43	-0.01	0.09	0.75	1.00
Convergent Validity (AVE)	0.57	0.63	0.69	0.60	0.47

In order to evaluate the formative measurement models, Chin (1998) suggests a threshold value of 0.10 for formative measures with the outer weights being tested for significance by means of the bootstrapping procedure with a 500 resample of construct level sign change and the number of cases equal to the original sample size. This was done for all three PLS weighting schemes (centroid weighting, factor weighting and path weighting). Table 6.4 shows this result, wherein it can be seen that overall there is no significant differences between outer weights for all schemes with an average outer weight of 0.42. The item SP5 was not significant in almost all cases. In addition, item SP2 was not significant in the factor weighting scheme. All other measured weights are significant at 0.01 and lie well above the suggested threshold of 0.10 in almost all cases.

Table 6.4: Outer weights

Construct	Item	Centroid weighting		Factor weighting		Path weighting	
		Weight	t-Statistic	Weight	t-Statistic	Weight	t-Statistic
Comprehension	CM3	0.44	2.65	0.51	3.18	0.50	3.18
	CM4	0.53	4.72	0.53	4.51	0.53	5.03
	CM5	0.44	3.38	0.39	3.37	0.39	3.69
Knowledge	KN2	0.33	2.85	0.31	2.60	0.32	2.92
	KN3	0.46	3.05	0.46	2.74	0.45	2.59
	KN4	0.50	4.46	0.51	5.00	0.51	6.17
Performance	PM1	0.32	2.49	0.32	2.23	0.32	2.83
	PM2	0.54	2.63	0.53	2.60	0.56	2.94
	PM4	0.35	2.43	0.35	2.47	0.34	2.60
Skills	SK3	0.59	4.94	0.61	7.35	0.61	7.35
	SK5	0.61	6.35	0.59	5.72	0.58	6.26
Support	SP1	0.38	4.11	0.38	3.93	0.37	4.46
	SP2	0.34	4.45	0.27	1.66	0.33	2.72
	SP4	0.34	2.89	0.37	2.20	0.33	2.64
	SP5	0.17	1.22	0.19	0.90	0.21	1.53
Average		0.42		0.42		0.42	

6.1.2 The Inner Model Measurement

The structural model was estimated after the determination of reliability and validity to assess the predictive power of the research model. The predictive power, which is also called coefficient of determination (R^2) of the main effect model, was calculated. Figure 6.1 shows this result in a screen shot of the structural model estimation in SmartPLS 2.0 software application.

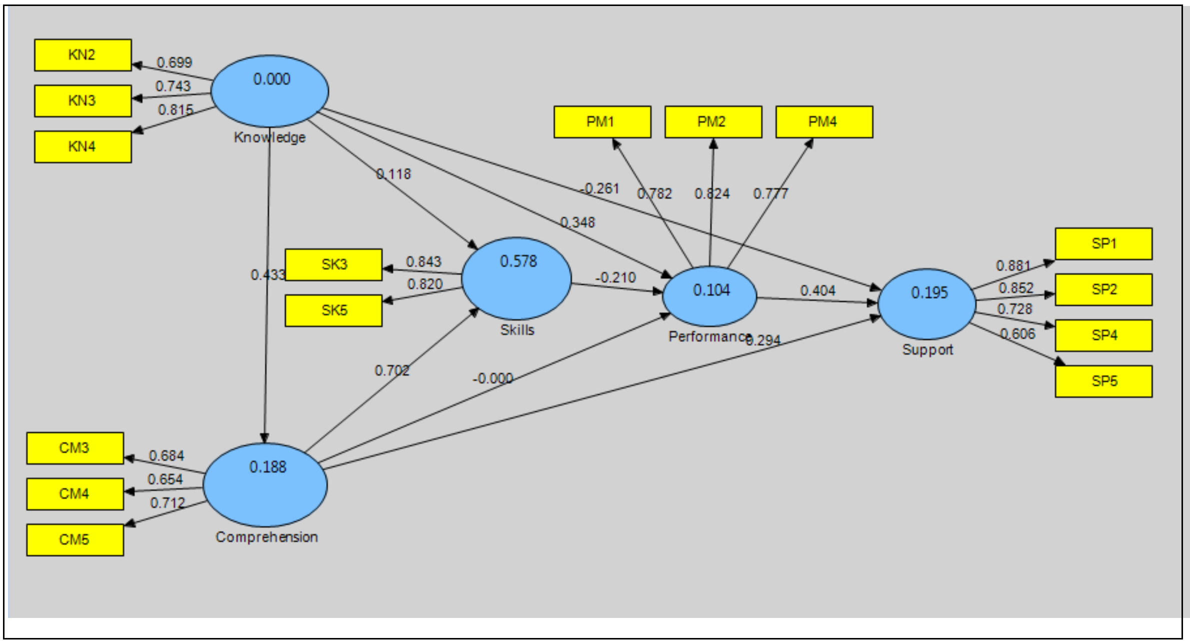


Figure 6.1: Structural equation model for main effects

The quality of each structural equation is measured by a simple evaluation of R^2 for all dependent factors. This was done for three PLS weighting schemes (centroid weighting, factor weighting and path weighting) and the result is shown in Table 6.5. The R^2 values associated with comprehension, skills and support are statistically significant from zero in all cases, but it was not significant for performance. R^2 values for comprehension, performance and support are quite low being less than 0.33 in all cases. The authors (Ringle et al., 2010) consider this value as a weak level for a PLS path model. In this study, R^2 values of a weak level has to be considered as unsatisfactory and could be used as a first sign of possible unobserved heterogeneity in the TSM data.

Table 6.5: Predictive power analysis

	Centroid weighting scheme		Factor weighting scheme		Path weighting scheme	
Factors	R^2	F	R^2	F	R^2	F
Comprehension	0.18*	15.21	0.19*	15.95	0.19*	15.95
Performance	0.09	2.18	0.10	2.58	0.10	2.58
Skills	0.57*	45.18	0.58*	46.61	0.58*	46.57
Support	0.20*	5.45	0.20*	5.56	0.19*	5.40
GoF	0.39		0.40		0.40	

*significant

The global evaluation criterion for the quality of a structural model is assessed through the GoF index (Tenenhaus et al., 2005) to give the data fit of the overall model to be 0.39 for the centroid weighting scheme, 0.40 for factor scheme and 0.40 for path weighting scheme. The model fit results for factor and path weighting schemes seem to be better than the centroid weighting scheme. The quite low value of the GoF index might also suggest the need to look for more homogeneous segments among the data sample. Although the quality of each structural equation is measured by the estimate of R^2 and GoF, this is not sufficient to evaluate the whole structural model. Specifically, because structural equations are estimated once a convergence is achieved and LV scores are estimated, R^2 values only take into account the fit of each regression equation in the structural model (Vinzi et al., 2010).

The cross validation communality (cv-communality) index measures the quality of outer model and is a kind of cross-validated R^2 between block of items and their own constructs. The quality of each inner model or structural equation is measured by the cv-redundancy index, which is a kind of cross-validated R^2 between items of a dependent factor and all items associated with factors explaining the dependent factor. For the TSM model, blindfolding has been carried out using an omission distance of value 7. According to Wold (1982), the omission distance should be an integer between the number of indicators and number of cases. Chin (1998) indicates that values between 5 and 10 are feasible but, considering the complexity of the model, the researcher believes that a larger number is preferable.

Table 6.6 shows this result for all the three PLS weighting schemes. As it can be seen, the comprehension block does not present an acceptable cross-validated communality index. Moreover, due to the blindfolding procedure, the cv-communality measure is negative in all cases, which happens in this study and according to Tenenhaus et al. (2005), this situation implies that the corresponding comprehension construct has been badly estimated. Nonetheless, all other constructs exhibited acceptable cross-validated redundancy and a cv-communality greater than zero in all the different PLS weighting schemes.

Table 6.6: Communality and redundancy

Construct	Centroid weighting		Factor weighting		Path weighting	
	Communality	Redundancy	Communality	Redundancy	Communality	Redundancy
Comprehension	-0.01	0.08	-0.02	0.07	-0.02	0.07
Knowledge	0.15		0.14		0.14	
Performance	0.25	0.03	0.25	0.03	0.25	0.03
Skills	0.13	0.36	0.13	0.37	0.13	0.36
Support	0.34	0.08	0.33	0.07	0.34	0.07
Average	0.17	0.14	0.16	0.14	0.17	0.13

This study tested direct effects between the model factors to establish the robustness of the developed TSM. The path coefficient, standard deviation and t-value of hypothesized causal paths were obtained using the SmartPLS 2.0 bootstrapping procedure with 1200 resample of construct level sign changes and number of cases equal to the original sample size. This was conducted for path weighting schemes as it better detected errors in causal path. Table 6.7 shows this result, wherein it can be seen that there is a direct relationship between user comprehension and skills across all weighting schemes and resample sizes with the highest path coefficient of 0.71 in factor and path weighting schemes. Similarly, construct of knowledge directly affects comprehension independent of the scheme and resample sizes with the path coefficient ranging from 0.42 to 0.45. User performance using ICT systems was found to directly affect user support for alternative village object metaphors with highest and negative path coefficients of 0.41 and 0.38 respectively. The effects of varying resample sizes did not seem to be significant, because resample sizes of 200, 400 and 800 exhibited a total of 11 significant relationships, but a resample size of 1200 resulted into 12 significant relationships. However, the difference is very small and this indicates a strong consistency in model construct relationships. The path weighting scheme had the lowest total of 12 significant relationships, followed by the factor weighing scheme with a total of 13 significant relationships and lastly, the centroid weighing scheme with 16 significant relationships.

Table 6.7: Path coefficient analysis

Path	Centroid weighting				Factor weighting				Path weighting			
	200	400	800	1200	200	400	800	1200	200	400	800	1200
Comprehension -> Performance	-0.01	-0.01	0.01	0.02	-0.02	-0.01	-0.02	-0.02	0.03	-0.01	-0.01	-0.01
Comprehension -> Skills	0.70*	0.70*	0.68*	0.68*	0.69*	0.70*	0.70*	0.71*	0.71*	0.71*	0.70*	0.70*
Comprehension -> Support	0.35*	0.29	0.34	0.34*	0.28	0.30	0.31	0.29	0.32	0.33	0.32	0.33
Knowledge -> Comprehension	0.42*	0.45*	0.43*	0.43*	0.45*	0.45*	0.44*	0.45*	0.44*	0.44*	0.45*	0.44*
Knowledge -> Performance	0.31	0.35*	0.33	0.35*	0.34	0.35	0.35*	0.34	0.34*	0.36*	0.34*	0.35*
Knowledge -> Skills	0.13	0.10	0.13	0.13	0.11	0.11	0.11	0.11	0.1	0.11	0.11	0.11
Knowledge -> Support	-0.25	-0.22	-0.24	-0.25	-0.22	-0.21	-0.22	-0.22	-0.27	-0.25	-0.26	-0.26
Performance -> Support	0.41*	0.40*	0.40*	0.38*	0.40*	0.40*	0.40*	0.40*	0.41*	0.38*	0.41*	0.40*
Skills -> Performance	-0.21	-0.19	-0.21	-0.22	-0.17*	-0.19	-0.19	-0.19	-0.23	-0.20	-0.2	-0.20

*significant

6.1.3 Heterogeneity Measurement

As discussed in Chapter 5, an important step in applying FIMIX-PLS is to identify the number of segments that characterized heterogeneity in sampled data. However, the number of segments is unknown and the identification of an appropriate number K of segments is not a straightforward task (Ringle et al. 2010). A statistically satisfactory solution does not exist for several reasons (Wedel and Kamakura, 2000). For this reason, Hahn et al. (2002) proposed a repeated operation of FIMIX-PLS with consecutive number K of segments (K=1, 2, ..., 10) and to compare the segment-specific outcomes for criteria such as the log likelihood Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Consistent AIC (CAIC) and Normed Entropy statistic (EN). The quality of the separation of the derived segments will improve with a higher value of EN, with a value above 0.5 implying that estimate permits unambiguous segmentation (Sarstedt and Ringle, 2010). This criterion is especially relevant for identifying and clustering different types of data samples in the field of technology support.

Table 6.8 shows this result to establish comparison for different numbers of segments. It can be seen that increase in the maximum number of iterations has improved the degree of separation in the individual estimated segment probabilities for three segments case. For instance, when K=3, EN has improved from 0.82 to 0.92. However, for K=2, increase in the maximum number of iterations did not affect EN values. The segment sizes in all segment cases (K=2 and K=3) reveal one large segment whose probability is greater than 0.6 for K=2 and greater than 0.40 for K=3. This result implies that data sample consists of a single large group of similar respondents and a fuzzy small group of respondents. Based on this result, segmentation based on K=3 with 1600 maximum iterations is appropriate for this study, resulting into three segments S1, S2, S3 (see Appendix B). It exhibited EN of 0.87 and positive for other criterion as compared to K=3 with 400 maximum iterations, which resulted into EN value of 0.92 and negative values for other criterion.

Table 6.8: Segments comparison

K	Maximum iteration	Akaike Information Criterion (AIC)	Bayesian Information Criteria (BIC)	Consistent AIC (CIAC)	Normed Entropy statistic (EN)	Relative segment size π_s		
						S=1	S=2	S=3
2	200	712.542	773.635	774.012	0.801	0.832	0.168	
	400	712.542	773.635	774.012	0.801	0.832	0.168	
	800	757.752	818.844	819.222	0.659	0.392	0.608	
	1600	712.543	773.635	774.012	0.801	0.832	0.168	
3	200	700.829	793.599	794.172	0.816	0.139	0.408	0.452
	400	-1458.969	-1366.199	-1365.626	0.923	0.692	0.451	0.371
	800	663.694	756.464	757.037	0.823	0.218	0.388	0.394
	1600	706.942	799.712	800.285	0.870	0.338	0.464	0.197

In next step of FIMIX-PLS, observations are assigned to each segment to provide membership probabilities for each observation to fit in any of the three segments. In order to segment the experimentation data on the basis of this result, each observation is assigned to a segment according to its maximum probability of segment membership. The three-segment solution identifies smallest size segment probability (0.20), mid-size segment probability (0.34) and largest size segment probability (0.46). Table 6.9 shows the maximum probability calculated by the FIMIX-PLS scheme for each case.

Table 6.9: Maximum probability for each case

Case	S1	S2	S3	Case	S1	S2	S3
1	0.333	0.012	0.655	37	0.774	0.047	0.179
2	0.074	0.882	0.044	38	0.297	0.595	0.108
3	0.708	0.048	0.244	39	0.102	0.679	0.219
4	0.781	0.054	0.165	40	0.268	0.398	0.334
5	0.906	0.024	0.070	41	0.218	0.523	0.259
6	0.831	0.047	0.122	42	0.838	0.042	0.120
7	0.316	0.119	0.565	43	0.927	0.032	0.041
8	0.322	0.171	0.507	44	0.390	0.484	0.126
9	0.161	0.581	0.258	45	0.948	0.045	0.007
10	0.871	0.108	0.021	46	0.245	0.419	0.336
11	0.239	0.443	0.318	47	0.200	0.483	0.317
12	0.571	0.199	0.230	48	0.196	0.390	0.414
13	0.223	0.723	0.054	49	0.972	0.006	0.022
14	0.821	0.140	0.039	50	0.339	0.432	0.229
15	0.256	0.689	0.055	51	0.959	0.029	0.012
16	0.939	0.044	0.017	52	0.996	0.001	0.003
17	0.625	0.361	0.014	53	0.024	0.509	0.467
18	0.829	0.020	0.151	54	0.510	0.281	0.209
19	0.200	0.753	0.047	55	0.926	0.033	0.041
20	0.041	0.814	0.145	56	0.638	0.012	0.350
21	0.824	0.023	0.153	57	0.876	0.044	0.080
22	0.181	0.139	0.680	58	0.775	0.078	0.147
23	0.479	0.134	0.387	59	0.840	0.072	0.088
24	0.260	0.434	0.306	60	0.538	0.204	0.258
25	0.709	0.077	0.214	61	0.882	0.104	0.014
26	0.599	0.150	0.251	62	0.441	0.292	0.267
27	0.592	0.039	0.369	63	0.170	0.229	0.601
28	0.085	0.876	0.039	64	0.453	0.254	0.293
29	0.885	0.042	0.073	65	0.714	0.102	0.184
30	0.341	0.468	0.191	66	0.615	0.311	0.074
31	0.985	0.014	0.001	67	0.475	0.223	0.302
32	0.496	0.190	0.314	68	0.251	0.267	0.482
33	0.477	0.071	0.452	69	0.907	0.004	0.089
34	0.860	0.103	0.037	70	0.729	0.106	0.165
35	0.280	0.172	0.548	71	0.683	0.129	0.188
36	0.266	0.143	0.591				

Subsequently, each segment is separately analysed by applying the standard PLS-PM algorithm using a path weighting scheme. All segment based path model estimations were tested for validity and reliability before evaluating GoF measures and inner model relationships. Path coefficients were tested for significance by means of the bootstrapping procedure with a 1200 resample of construct level sign change and the number of cases equal to the original sample size. Table 6.10 shows the result of global model, FIMIX-PLS path coefficient and GoF measures for the three segments. In the global model, only four direct path coefficients (0.44, 0.35, 0.70 and 0.40) are significant. The direct path coefficients (0.11, -0.26, -0.01, 0.33, -0.20) are found to be insignificant. These results provide evidence to accept direct hypotheses H1, H3, H5 and H9 and reject direct hypotheses H2, H4, H6, H7 and H8. Table 6.10 also shows that hypothesis H5 is globally and locally significant because it is significant in both segments. The local models are found to be better than the global model because their GoF values are higher in the three segments than for the global model.

Table 6.10: Path coefficients and GoF measures

Path	Global	FIMIX-PLS			t [mgp]		
		S1	S2	S3	S1 and S2	S1 and S3	S2 and S3
Comprehension -> Performance	-0.01	0.32	0.33*	2.60***	-0.02*	-4.78***	-2.86*
Comprehension -> Skills	0.70***	0.78***	0.43*	1.00***	1.50*	-1.04*	-5.10***
Comprehension -> Support	0.33	0.63*	-0.11	0.54*	1.90*	0.23*	-1.60*
Knowledge -> Comprehension	0.44**	0.70***	0.51***	-0.07	1.29*	4.47***	3.40**
Knowledge -> Performance	0.35*	0.44	0.28	0.00	0.48*	2.34*	0.99*
Knowledge -> Skills	0.11	0.04	0.21	0.09	-0.80*	-0.27*	1.04*
Knowledge -> Support	-0.26	-0.70*	-0.28	-0.38*	-1.24*	-1.33*	0.31*
Performance -> Support	0.40*	0.01	-0.13	0.77*	0.43*	-2.02*	-2.00*
Skills -> Performance	-0.20	-0.27	-0.25	-3.50***	-0.03*	6.20***	4.90***
R^2 Comprehension	0.19	0.51	0.26	0.00			
R^2 Performance	0.10	0.49	0.20	1.00			
R^2 Skills	0.58	0.65	0.34	0.99			
R^2 Support	0.19	0.31	0.21	0.53			
GoF	0.40	0.49	0.37	0.70			

*p<0.5, **p<0.001 and ***p<0.0001. T[mgp] = t-value for multi-group comparison

The final step of FIMIX-PLS involves the identification of a certain response factor to characterize the three uncovered user segments using demographic characteristics. The purpose was to determine whether culture characterises the three identified segments. Table 6.11 shows the result of descriptive analysis of segmentation based on culture, wherein it can be seen that majority (50%) of participants in the first and third segments portray the culture associated with black ethnic group. In the second segment, majority (51.5%) of participants portray culture associated with Indians ethnic group. In essence, it can be inferred that the three segments actually differ based on cultural values associated with certain ethnic groups of respondents and this marks the basis of segmentation applied to the observation data.

Table 6.11 Descriptive analysis of segmentation based on culture

Response	Segment 1	Segment 2	Segment 3
1- Black	50.0	33.3	50.0
2- White/Coloured	4.2	15.2	7.1
3-Indian	45.8	51.5	42.9
Total	100.0	100.0	100.0

6.2 Discussion of Results

The purpose of this section is to discuss the results of the research questions raised in this study. Consequently, the section is organized into three main themes, user support for alternative interface metaphors, effects of culture on user support for alternative interface metaphors and user response characteristics. The researcher has solved three research questions that have to do with identifying factors which will most likely influence the support of African rural users for alternative village object metaphors as interface icons, determining that culture will have effects on the support of African rural users for alternative African village object metaphors as user interface icons and discovering response characteristics that differ among African rural users in their support for alternative interface metaphors. In doing so, a participatory approach based on cultural probes and bodystorming was applied. In general, participatory design is regarded as an effective approach in system development processes to overcome the challenges of changing contexts, difficulties of eliciting user requirements and problems of achieving wider adoption as well as support for ICT systems. However, user participation is ICT systems design is often associated with certain contextual assumptions, which are based on western culture that are not always directly applicable to the situations in the African countries, especially the rural settings.

6.2.1 *User Support for Alternative Interface Metaphors*

The test for the effects of each of the independent factors of knowledge, comprehension, skills and performance on the dependent factor of support was determined by calculating R^2 values. This was done to determine the factors that impact on support, when each factor was excluded and when it was included in the analysis. The effect size, which is based on the two R^2 values, was computed and tested for statistical significance. Table 6.12 shows this result, wherein it can be seen that the effect size of knowledge, performance and comprehension on support is of small to medium size, but are found to be significant. The performance factor exhibited the highest effect size (0.12) followed by comprehension (0.06) and knowledge (0.04). The skills factor, which exhibited a negative effect size (-0.02) gives the least effect size. This result implies that performance is the most important factor in the prediction of user support for African village object metaphors. However, the skills factor does not contribute to the R^2 value of support at all.

Table 6.12: Test of effect size of independent factors

Independent Factor	R^2 included	R^2 excluded	f^2	F
knowledge	0.195	0.162	0.04	2.71*
Skills	0.195	0.211	-0.02	-1.31
Performance	0.195	0.099	0.12	7.87*
Comprehension	0.195	0.149	0.06	3.77*

*significant

The researcher also went further to assess the deep contribution of the performance factor as mediator on the relationship between knowledge and comprehension on support. The hypothesized causal paths were estimated and the mediation effect size was determined. This result is to validate hypotheses H13 and H14. Table 6.13 shows that performance factor does not mediate the relationship between knowledge and support (z-value=1.797 and p-value=0.0723 are estimated), hypothesis (H13) was therefore rejected. Similarly, user performance did not mediate the effect of user comprehension of user interface on user support for alternative village metaphors. This study estimated z-value of -0.063 and p-value of 0.9495 and hypothesis (H14) was therefore also rejected. It can be concluded that user knowledge did not directly or indirectly affect user support for the metaphors. However, user comprehension had a direct effect on user support for alternative village object metaphors, but did not have an indirect effect through user performance. This result was expected as one does not necessary have to master the use of a technology to declare support for the technology. In addition, users would most likely support any technology that can help to increase their business performance.

Table 6.13: Performance mediating effect analysis

Hypothesis	Path	z-value	p-value
H13	Knowledge -> Performance -> Support	1.797	0.0723
H14	Comprehension -> Performance -> Support	-0.063	0.9495

*significant

In order to determine which of the two factors (concrete and office knowledge) exerts a greater effect on user skills, this study compared the path ConcreteKnowledge -> User Skills against OfficeKnowledge -> User Skills. Figure 6.2 shows the screen shot of the experiment using SmartPLS 2.0 software application.

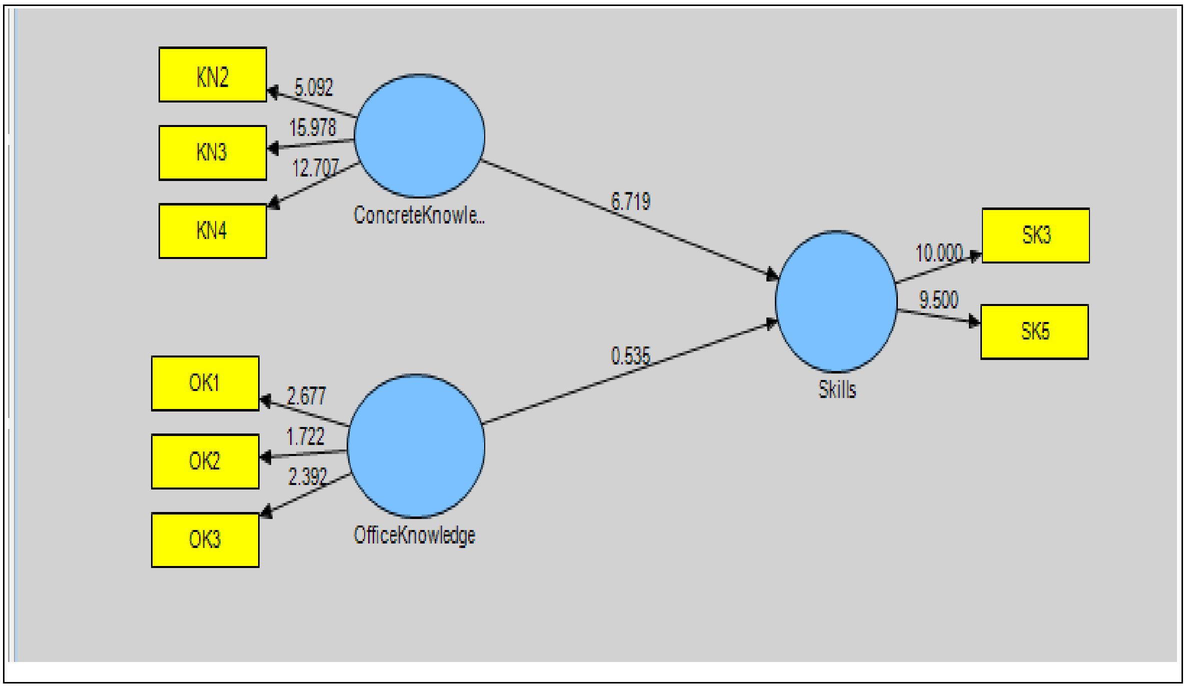


Figure 6.2: User skills predicted in terms of concrete and office knowledge

The path coefficients were computed through bootstrapping and were compared for statistical difference. The result shows that the two path coefficients (0.45 and 0.14) presented in Table 6.14 are statistically different from each other with an estimated t-value of 3.25 and p-value of 0.0007. Hence, it can be concluded that concrete knowledge has a greater effect on user skills as compared to office knowledge.

Table 6.14: Concrete and office knowledge effects analysis

Path	Path coefficient	Stdev	t-value	p-value
ConcreteKnowledge -> User Skills	0.45	0.06	7.13	0.0001*
OfficeKnowledge -> User Skills	0.14	0.07	0.53	0.5948

*significant

6.2.2 Effects of Culture on User Support for Alternative Interface Metaphors

The test for whether culture has a moderating effect in the relationships involving independent constructs of user knowledge, comprehension, skills and dependent construct of user support was determined by calculating R^2 values for user support when culture was excluded and when it was included. The effect size based on these two R^2 values was computed and tested for statistical significance. Table 6.15 shows this result, wherein culture was found to moderate the effects of user performance on user support with an estimated effects size of 0.207 and F-value of 13.241. This result gave evidence to support hypothesis (H10) that culture moderates effects of user performance on user support. Culture was also found to moderate the relationship between user comprehension of user interface object metaphors and user support for the village object metaphors with the estimated effect size of 0.092 and F-value of 5.905. The hypothesis (H11) that culture moderates effects of user comprehension on user support for village object metaphors was accepted. In addition, effects of culture on relationship between user knowledge and user support is significant with effect size of 0.106 and F-value of 6.769. This implies that the effect of user knowledge on user support for village object metaphors is influenced by culture. The hypothesis (H12) that culture moderates effects of user knowledge on user support was accepted.

Table 6.15: Culture moderating effect analysis

Hypothesis	Construct	R^2 included	R^2 excluded	f^2	F
H10	Knowledge	0.272	0.195	0.106	6.769*
H11	Comprehension	0.263	0.195	0.092	5.905*
H12	Performance	0.333	0.195	0.207	13.241*

*significant

In order to understand the overall value of culture on user support for alternative village metaphors, predictive power of the research model was compared with the culture moderated research model as shown in Figure 6.3. The effect size based on R^2 values of the independent factor of user support is computed and tested for statistical significance using appropriate mathematical equations (see Appendix A). The effect size of 0.292 and F-value of 18.697 indicate that culture improves the R^2 value of TSM. It can be concluded therefore that the moderated TSM better predicts user support for alternative village objects for interface metaphors.

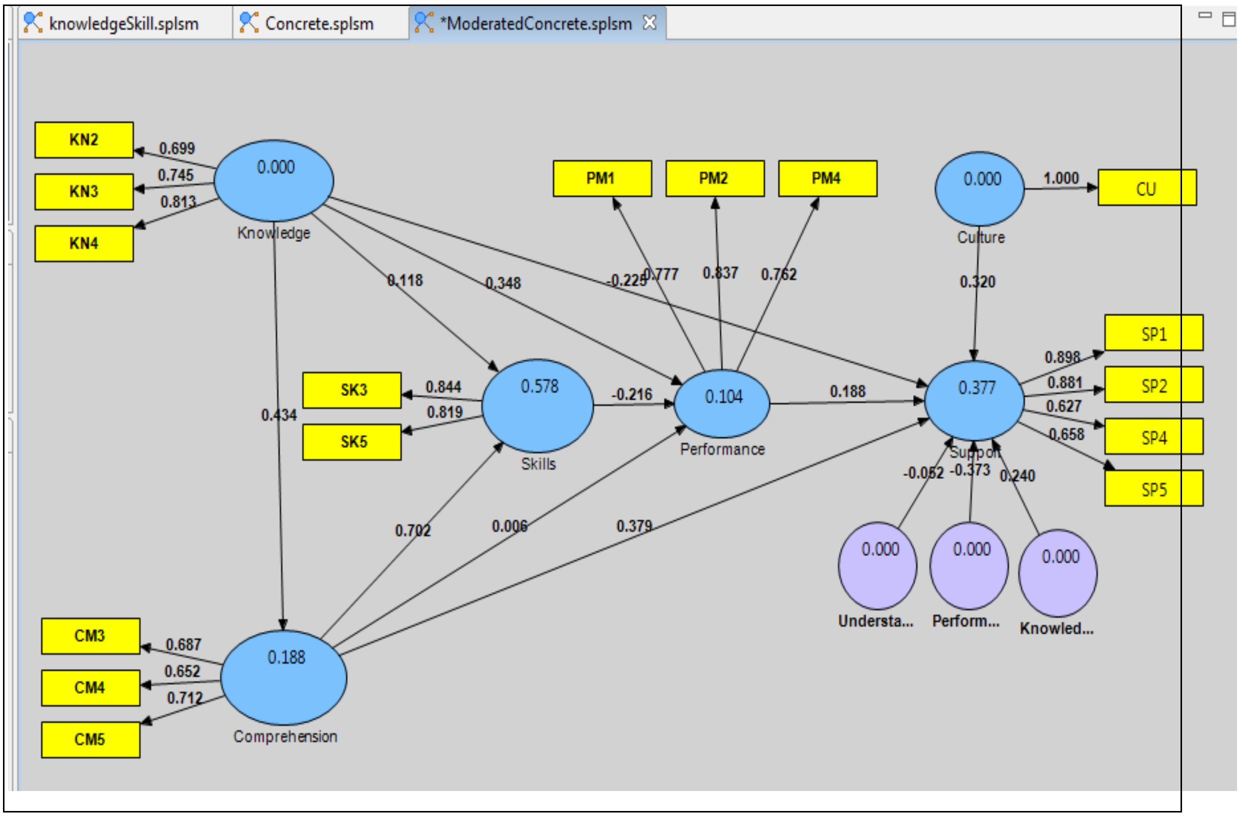


Figure 6.3: Structural equation model for culture moderated effects

6.2.3 User Response Characteristics

The treatment of heterogeneity using FIMIX-PLS segmentation analysis method provides the means to uncover the response characteristics of African rural users. This study identifies three segments to capture the response characteristics of African rural users of ICT systems. The response characteristic was detected through the culture. There was differing opinions among members of the three segments regarding their support for alternative village metaphors as interface metaphors.

Chapter 7 Summary, Further Work, Conclusion

This chapter gives the summary of the work done in this exploratory study. This is followed by the delineation of future work and concludes with a brief statement of the potential benefits of the work.

7.1 Summary

The current computer interface metaphors are usually designed based on the desktop metaphors, which assume that people use computers in a work or an office environment seated behind a desk. Such people are therefore supposed to be familiar with office objects such as scissors, envelopes, folders, files and clipboards whose recognition level is naturally expected to stay high when translated into metaphors for computer interfaces. The reality is that the profiles of computer users have now extended beyond office workers and the scope of e-literacy has also expanded far beyond computer literacy. This is becoming more and more obvious with the deployment of telecentres and internet kiosks worldwide (Patel et al., 2006; Matthee, et al., 2007) and with the huge adoption of cellular telephones (Richards and Van Belle, 2006) by illiterate people not involved in any office work as is the case in general in the developing world and in particular in Africa. This current study presents the research done in an attempt to answer the research questions of what factors influence support of African rural users for effective ICT utilization, what is the extent that Africa rural users will be able to associate African village metaphors to computer actions and what effects will culture have on the support of African rural users for alternative African village object metaphors as interface metaphors. The Technology Support Model (TSM) was developed and applied to answer these questions.

The context of this study considers the African diversity with many illiterate indigenous populations not involved in any type of office work, whose lives are rooted in the African culture and who coexist with other literate and educated (both indigenous and non-indigenous) people usually involved in office work. The metaphors approach is used for different computer user interfaces and their cultural context were examined to establish whether more culturally specific metaphors could improve usability of the user interface and thereby improve the level of computer literacy. The results from preliminary research with a rural community (Heukelman, 2006) indicated that some of the current metaphors are not well recognized and further research was indicated. The rationale behind this current research is well captured by the following quote. Researchers "agree upon the fact that designers should not just change text and date, number and time formats, but should also pay attention to aspects such as collating sequences, metaphors, symbols, colours, flow of dialogues, title bars, status messages" and others (Evers, 1998).

This study solves three important research questions summarized along with their solutions as follows.

a) What are the factors that will likely influence the support of African rural users for alternative village object metaphors as interface metaphors? The human cognitive factors of ICT knowledge, ICT comprehension and performance with ICT have significant influence on African rural user support for alternative village object metaphors as interface metaphors. The performance factor appears to be the most important factor that predicts user support for alternative African village object metaphors.

b) What effects will culture have on the support of African rural users for alternative African village object metaphors as user interface metaphors? The factor of culture was found to moderate user support for African village object metaphors. In addition, culture was found to moderate the relationship between user comprehension of user interface object metaphors and effects of user performance using ICT systems. It can be concluded therefore that culture moderated TSM better predicts user support for alternative African village metaphors than un-moderated TSM.

c) What response characteristics will differ among African rural users in their support for alternative interface metaphors? The response characteristic was detected to be culture by the aid of FIMIX-PLS segmentation method. This implies that culture characterises heterogeneity in the TSM data and splits the data into three segments of people who share common beliefs and views about alternative village metaphors as user interface icons.

The distinctive contribution made in this study lies in the development of a TSM, which is a new model to empirically determine the support of users for a technology. The model was validated to establish the effects of culture on relationships between constructs of knowledge, comprehension, skills and support. In comparison to the existing technology adoption models, TSM is unique because it utilizes human cognitive properties to explain or predict human support for technology. TSM is well suited for both pre and post adoption regimes and can be applied to individuals to determine their support for a particular technology. Specifically, the contributions of this study to the HCI body of knowledge are summarized as follows.

a) The development of a participatory framework based on cultural probes and bodystorming to examine the support of African rural users for alternative African village metaphors as interface icons.
b) The development of technology support model based on human cognitive properties instead of technology characteristics that can be used to establish support for ICT systems.
c) The empirical establishment of the effects that cultural diversities can have on human support for ICT systems.
d) The empirical identification of human cognitive characteristics that affect human support for ICT systems.
e) The empirical study of heterogeneity detection in HCI survey data generated from African rural users participatory experience.

7.2 Further Work

Frankly speaking, an exciting aspect of this study is that an additional support was provided for a theory that has the potential of breaking some of the mirrors in technology adoption research. Using the TSM, it is possible to determine for instance, a high level management support for a new technology based on prior experiences, knowledge, skills and performance with a similar existing system. Clearly, the results of this study provide some more support for the idea that the contributions of specific factors should be further examined. Although the results need to be replicated and the model validated within diverse application domains before more definitive statements can be made. It is also important to further examine the predictive power and predictive relevance of the model by conducting a longitudinal study versus the cross-sectional approach for further tests. Specifically, in future the researcher desires to further test the TSM in other technology support domains different from HCI, study heterogeneity in a large HCI survey data, test the TSM on a large dataset, compare the predictive power and predictive relevance of user support for diverse cultural groups.

7.3. Conclusion

This exploratory research work applies a synthesis methodology that integrates valuable aspects of bodystorming and cultural probes approaches to engage African rural users in a participatory user interface study. The goal of the synthesis methodology was to guide the designers of information systems on how to engage real users in the design of human computer interaction concrete object metaphors for African users. This will allow for the ultimate wider usability of information systems and provide a robust mechanism to solicit the cooperation of users in system design process.

Resulting from this synthesis methodology is the development of a TSM that can be generally used to determine user support for a technology. The TSM can be applied to objective and subjective determination of potential issues in system supports. The TSM is a choice model for pre and post technology adoption and support assessment. TSM completely differs from existing technology adoption models in that it purely relies on user characteristics such as experience, knowledge, comprehension and skills to predict user support for a new technology. The extant adoption theories heavily rely on system characteristics such as perceived ease of use and perceived usefulness. In conclusion, the TSM has brought about fresh ideas to ongoing discourse about the usefulness of different approaches to studying technology adoption, which has received a lot of criticism in recent times (Bagozzi, 2007; Benbasat and Barki, 2007; Bhattacherjee and Sanford, 2009; Chuttur, 2009; Brandyberry, 2011). This thesis presents a TSM as an alternative to TAM to better understand technology adoption issues from a user perspective.

This study recommends the application of TSM in various technology adoption studies. This model needs to be tested and comments on its usefulness and applicability to further improve the model and promotes its uses for a wider applicability. This study also provides an application of FIMIX-PLS to capture heterogeneity in PLS path modelling of user knowledge, comprehension, skills, performance and user support for alternative African village metaphors. This approach has enabled the researcher to identify three segments of African rural users that result in heterogeneity within the inner path model.

Bibliography

Achidi, A. U., Ajayi, O. A., Bokanga, M. and Maziya-Dixon, B. 2005. The Use of Cassava Leaves as Food in Africa. *Ecology of Food and Nutrition*, 44(6), 423-435.

Aibinu, A. and Al-Lawati, A.M. 2010. Using PLS-SEM technique to model construction organizations' willingness to participate in e-bidding. *Automation in Construction*, 19 (6), 714-724.

Akaike, H. 1973. Information Theory and an Extension of the Maximum Likelihood Principle. In B.N. Petrov and Casaki (Eds.), Second International Symposium on information theory, 267-281. Budapest: Akademiai Kiado.

Albers, S. 2010. PLS and success factor studies in marketing. In V. E. Vinzi, W. W. Chin, J. Henseler and H. Wang (Eds.), Handbook of Partial Least Squares. Heidelberg: Springer.

Amireault, S., Godin, G., Vohl, M. and Pérusse, L. 2008. Moderators of the intention-behaviour and perceived behavioural control-behaviour relationships for leisure-time physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, 5(1), 1-11.

Andreasen, M. S., Nielsen, H., Schroder, S. O. and Stage, J. 2007. What Happened to Remote Usability Testing? An Empirical Study of Three Methods. Proceedings of CHI 2007 Conference. San Jose, CA, USA: ACM.

Antle, A.N., Corness,G., Bakker,S. Droumeva,M., Hoven, E.V.D. and Bevans, A. 2009. Designing to support reasoned imagination through embodied metaphor. Proceedings of the seventh ACM Conference on Creativity and Cognition, 275-284.

Ashok, A. and Beck, C. 2007. Using Activity Theory to Develop a Design Framework for Rural Development. Proceedings of CHI 2007 Conference, 2255-2260, San Jose, California, USA: ACM.

Asokan, A. and Cagan, J. 2005. Defining Cultural Identities Using Grammars: an Exploration of Cultural Languages to Create Meaningful Experiences. Proceedings of the Conference on Designing for User eXperience, 209–224.

Averbukh, V.L. 2008. Searching and Analysis of Interface and Visualization Metaphors. Human-Computer Interaction, New Developments. Chapter 3, Vienna, 49-84.

Averweg, U., Barraclough, C. and Spencer, A. 2003. Usability factors and ‘e-readiness’ for the development of the eThekwini online website. Available: http://www.chi-sa.org.za/chisa2003/Abstracts%20for%20CHISA.pdf [Accessed 14 May 2007].

Bagozzi, R.P. 2007. The legacy of the technology acceptance model and a proposal for a paradigm shift. *Journal of the Association for Information Systems*, 8 (4), 244–254.

Barber, W. and Badre, A. 1998. Culturability: The merging of Culture and Usability. Proceedings of the 4th Conference on Human Factors and the Web, Basking Ridge NJ, June.

Baron, R.M. and Kenny, D.A. 1986. The moderator-mediator variable distinction in social psychological research: conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173-1182.

Barr, P., Khaled, R., Noble, J. and Biddle, R. 2005. A Taxonomic Analysis of User-Interface Metaphors in the Microsoft Office Project Gallery. 6th Australasian User Interface Conference AUIC2005, Newcastle.

Batavia, P., Pomerleau, D.A. and Thorpe, C.E. 1997. Overtaking Vehicle Detection Using Implicit Optical Flow. Proceedings of the IEEE Transportation Systems Conference, November, 729 - 734.

Becker, J., Ringle,C.M. and Völckner, F. 2009. Prediction-Oriented Segmentation: A New Methodology to Uncover Unobserved Heterogeneity in PLS Path Models. Proceedings of the 38th Annual Conference of the European Marketing Academy, Nantes, France, CD-Rom Proceedings.

Bell, B. 1992. Using programming walkthroughs to design a visual language. Technical Report CU-CS-581-92 (Ph.D. Thesis), *University of Colorado, Boulder, CO*.

Benbasat, I. and Barki, H. 2007. Quo vadis, TAM? *Journal of the Association for Information Systems*, 8(4), 211–218.

Benyon, D. and Murray, D. 1988. Experience with adaptive interfaces. *The Computer Journal*, 31(50), 465-473.

Berman, S.D. 2008. Technical Evaluation Report 65. ICT-based Distance Education in South Asia. *International Review of Open and Distance Learning*, 9(3), October.

Beukes, E.M., Bester, B.H. and Mostert, J.F. 2001. The microbiology of South African traditional fermented milks. *International Journal of Food Microbiology*, 63(3), February, 189-197.

Bhattacherjee, A. and Sanford, C. 2009. The intention–behaviour gap in technology usage: the moderating role of attitude strength. *Behaviour and Information Technology*, 28(4), 389-401.

Bias, R. 1991. Walkthroughs: Efficient collaborative testing. *IEEE Software*. 8(5), 94-95.

Blake, E. and Tucker, W. 2006. User Interfaces for communication bridges across the digital divide. *Journal of AI and SOC*, 20(2), 232-242.

Bozdogan, H. 1987. Model Selection and Akaike Information Criterion (AIC): The General Theory and Its Analytic Extensions. *Psychometrika* 52(3), 345-370.

Bozdogan, H. 1994. Mixture-Model Cluster Analysis using Model Selection Criteria and a New Information Measure of Complexity. In Proceedings of the First US/Japan Conference on Frontiers of Statistical Modelling: An Information Approach, 69-113.

Brandyberry, A. 2011. A conceptual framework for sequential organizational technology adoption with dynamic goal and action portfolios. AMCIS 2011 Proceedings, 4-7 August, 2011, Detroit, USA.

Brock, F.J. and Newman, W.J. 1994. Testing Recognition of Computer-generated Icons. *Journal of Information Systems Education*, Winter 1993/1994, 18-22.

Burns, C., Dishman, E., Verplank, B. and Lassiter, B. 1994. Actors, hair-dos and videotape: informance design; using performance techniques in multi-disciplinary, observation based design. Proceedings of HI'94 Conference Companion 4/94, Boston, MA.

Cao, X and Kurniawan, S.H. 2007. Designing Mobile Phone Interface with Children. Proceedings of CHI '07 Conference extended abstracts on Human Factors in Computing Systems, ACM NY, USA.

Carlson, R.G. 1990. Banana Beer, Reciprocity and Ancestor Propitiation among the Haya of Bukoba, Tanzania. *Ethnology*, 29(4), October, 297-311.

Carney, J.A. 1998. The Role of African Rice and Slaves in the History of Rice Cultivation in the Americas. *Human Ecology*, 26(4), 525-545.

Carroll, J. B. 1993. Human cognitive abilities: a survey of factor-analytic studies. New York: Cambridge Univ. Press.

Carroll, J.M. and Carrithers, C. 1984. Training Wheels in a User Interface. *Communications of the* ACM, 27 (8): 800-806.

Carroll, J.M. and Rosson, M.B. 2007. Participatory design in Community Informatics. *Design Studies*. 28, 243-261.

Cattell, R.B. 1967. The theory of fluid and crystallised intelligence checked at 5-6 year old level. *British Journal of Educational Psychology*, 37(2), 209-224.

Cattell, R. B. 1987. *Intelligence: Its structure, growth and action*. Elsevier Science Publishers BV. Amsterdam: North Holland.

Chamorro-Premuzic, T., Furnham, A. and Ackerman, P.L. 2006. Ability and personality correlates of general knowledge. *Personality and Individual Differences*, 41(3), 419–429.

Center for Community Informatics Research, Development and Training. [Online]. Available: http://www.communityinformatics.net/.[Accessed 18 June 2012].

Chang, B.L., Bakken, S., Brown, S.S., Housten, T.K. 2004. Bridging the Digital Divide: Reaching Vulnerable Populations. *Journal of America Medical Informatics Association*, 11(6), 448-457.

Chatelin, Y.M., Vinzi, V.E. and Tenenhaus, M. 2002. State-of-art on PLS Path Modeling through the Available Software [online]. Available: http://www.hec.fr/var/fre/storage/original/application/d713bfa13eff075210485ada1a2f7c48.pdf. [Accessed 12 June 2012]

Chen, P. 2003. Towards a Methodology of Graphical Icon Design. Proceedings of IEEE Fifth International Symposium on Multimedia Software Engineering, 120.

Cheng, H-I and Patterson, P.E. 2007. Iconic hyperlinks on e-commerce websites. *Applied Ergonomics*, 38(1), January, 65-69.

Chetty, M., Tucker, W. and Blake, E. 2004. Developing Locally Relevant Software Applications for Rural Areas: A South African Example. Proceedings of Conference SAICSIT, 239-243.

Chin, W.W. 1998. The partial least squares approach for structural equation modeling, In Modern Methods for Business Research, G.A. Marcoulides, (Ed.), Lawrence Erlbaum Associates, London, 295–336.

Chin, W. W. 2000. Frequently asked questions – Partial Least Squares and PLS-Graph [online] Available: http://disc-nt.cba.uh.edu/chin/plsfac.htm. [Accessed 16 June 2012].

Chin, W.W., Marcolin, B. L. and Newsted, P.R. 2003. A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research*, 14 (2), 189-217.

Chun, M.M, Jiang, Y. 1998. Contextual cueing: implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, 36, 28–71.

Chuttur, M.Y. 2009. Overview of the technology acceptance model: origins, developments and future directions. *Sprouts: Working Papers on Information Systems*, 9(37). Indiana University, USA. http://sprouts.aisnet.org/9-37.

Cohen, J., 1988. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum.

Cornell, J.A. and Berger, R.D. 1987. Factors that influence the value of the coefficient of determination in simple linear and nonlinear regression models. *Phytopathology*, 77 (1), 63-70.

Cuncliffe, D. and Roberts-Young, D. 2005. Online design for bilingual civil society: a Welsh perspective. *Interacting with Computers* , 17(1), 85-104.

Das, D. 2010. Development of E-health applications for rural community of Bangladesh. *Journal of Theoretical and Applied Information Technology*, 43-56.

Davis, F.D., Bagozzi, R.P. and Warshaw, P.R. 1992. Extrinsic and intrinsic motivation to use computers in workplace. *Journal of Applied Social Psychology*, 22(14), 1111-32.

Davis, F.D. 1989. Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.

Davison, A.C. and Hinkley, D.V. 2003. Bootstrap methods and their application (2nd ed.). New York, NY: Cambridge University Press.

Denny, R.M. and Sunderland, P.L. 2004. Researching cultural metaphors in action: metaphors of computing technology in comtemporary U.S. life. *Journal of Business Research*, 58, 1456-1463.

Duncker, E. 2002. Cross-cultural usability of the library metaphor. Proceedings of the 2nd ACM/IEEE-CS joint Conference on Digital libraries, July 14-18, Portland, Oregon, USA.

Eberl, M. 2010. An application of PLS in multi-group analysis: The need for differentiated corporate-level marketing in the mobile communications industry. *Handbook of Partial Least Squares*, 487-514.

Efron, B. and Tibshirani, R.J. 1993. *An introduction to the bootstrap*. New York, NY: Chapman Hall.

Eisma, R., Dickinson, A., Goodman, J., Syme, A., Tiwari, L. and Newell, A. 2004. Early user involvement in the development of information technology-related products for older people. *Universal Access in the Information Society*, 3(2), 131-140.

Erickson, T. D. 1990. Working with interface metaphors, in B. Laurel, ed., ‘The Art of Human-Computer Interface Design’, Addison-Wesley Publishing Company, 65–73.

Erumban, A.A. and De Jong, S.B. 2006. Cross-country differences in ICT adoption: A consequence of Culture? *Journal of World Business*, 41(4), 302-314.

Escofier, B. and Pages, J. 1988. Analyses factorielles multiples: objectifs, méthodes et interprétation. Paris: Dunod.

Evers, V. 1998. Cross-cultural understanding of metaphors in interface design. Proceedings CATAC'98 Conference, Cultural Attitudes towards Technology and Communication, 1-3 August, Science Museum London, University of Australia.

Evers, V., Kukulska-Hulme, A. and Jones, A. 1999. Cross-Cultural Understanding of Interface Design: A Cross-Cultural Analysis of Icon Recognition. Proceedings of the International Workshop on Internationalisation of Products and Systems, IWIPS Rochester, New York, 20-22 May.

Faulkner, L. and Wick, D. 2005. Cross-user analysis: Benefits of skill level comparison in usability testing. *Interacting with Computers*, 773-786.

Ferreira, J., Noble, J. and Biddle, R. 2006. A Case for Iconic Icons. Proceedings of AUIC2006 Conference. Hobart, Australia: Wayne Piekarsky (Ed).

Ferris, T.L.J. 2009. On the Method of Research for Systems Engineering. Proceedings of 7th Annual Conference on Systems Engineering Research, Loughborough University, 20 - 23 April.

Fishbein, M. and Ajzen, I. 1975. Belief, attitude, intention and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley. Available: http://people.umass.edu/aizen/f&a1975.html.

Fiske, A.P. 1990. Relativity within Moose ("Mossi") Culture: Four Incommensurable Models for Social Relationships. *Ethos: Moral Relativism*, 18(2), June, 180-204.

Ford, G. and Gelderblom, H. 2003. The Effects of Culture on Performance Achieved Through the Use of Human Computer Interaction. Proceedings of Conference SAICSIT, 218-230.

Fornell, C. and Larcker, D.F. 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18 (1), 39-50.

Fornell, C and Bookstein, F.L. 1982. Two structural equation models: LISREL and PLS applied to consumer exit-voice theory. Journal of Marketing Research, 19(4):440–452.

Frank, I.E. and Friedman, J.H. 1993. A statistical view of chemometrics regression tools. *Technometrics*, 35, 109–148.

Gaver, W.W., Dunne, A. and Pacenti, E. 1999. Cultural Probes. *ACM Interactions* 6(1), 21-29.

Gaver, W.W., Boucher, A., Penningto, S. and Walker, B. 2004. Cultural probes and the value of uncertainty. *ACM Interactions*, September and October, 11(5), 53 - 56

Geladi, P. and Kowlaski B. 1986. Partial Least Square Regression: A tutorial. *Analytica Chemica Acta*, 35, 1–17.

Godden, D.R., Baddeley, A.D. 1975. Context-dependent memory in two natural environments: on land and underwater. *British Journal of Psychology*, 66(3), 325–331.

Goodhue, D., Lewis, W. and Thompson, R. 2006. PLS, Small Sample Size and Statistical Power in MIS Research. Proceedings of the 39th Hawaii International Conference on System Sciences, R. Sprague Jr. (Ed.), Los Alamitos, CA: IEEE, Computer Society Press.

Goodhue, D. and Thompson, R. 1995. Task-Technology Fit and Individual Performance. *MIS Quartely*, 19(2), 213-236.

Goonetilleke, R.S., Shih, H.M., On, H.K. and Fritsch, J. 2001. Effects of training and representational characteristics in icon design. *International Journal Human-Computer Studies*, 55, 741-760.

Gregor, P., Newell, A. and Zajicek, M. 2002. Designing for Dynamic Diversity – interfaces for older people. Proceedings of ASSETS Conference, 151-156. Edinburgh, Scotland: ACM.

Griep, M.I., Wakeling, I.N., Vankeerberghen, P. and Massart, D.L. 1995. Comparison of semirobust and robust partial least squares procedures. *Chemom. Intell. Lab. Syst*. 29(1), 37–50.

Gurstein, M. 2006. What is Community Informatics? [online]. Available: http://www. communityinformatics.net/ [Accessed 30 May 2012].

Hahn, C.H., Michael D.J. andreas, H. and Frank, H. 2002, Capturing Customer Heterogeneity Using a Finite Mixture PLS Approach, *sbr* 54, 243-269.

Hahn, C., Johnson, M. D., Herrmann, A. and Huber, F. 2002 Schmalenbach Business Review, 54, 243-269.

Hair, J.F., Black, W.C., Babin, B.J. anderson, R.E., Tatham, R.L. 2006. *Multivariate data analysis*. 6th ed. Upper Saddle River: Prentice Hall.

Hammel, A., White, C., Pfeiffer, S. and Miller,D. 2000. Pre-colonial mining in South Africa. *Journal of the South African Institute of Mining Metallurgy*¸- January/February, 49-56.

Harkness, S., Keefer, C.H. and Super, C.M. 2009. Culture and Ethnicity, In Developmental-Behavioural Pediatrics, By William B. Carey, Allen C. Crocker, William L. Coleman, Heidi M. Feldman, Ellen Roy Elias, Elsevier Health Sciences,p. 183.

Haseloff, A. and Ghadially, R. 2007. Gender, cybercafes and internet access: bridging the digital divide? In Rehana Ghadially, (Ed.), U*rban women in contemporary Indian*. New Delhi: Sage, 270-283.

Heimgärtner, R. 2006. Measuring Cultural Differences in Human Computer Interaction as Preparatory Work for Cross-Cultural Adaptability in Navigation Systems. In: Useware 2006, VDI-Bericht Nr. 1946, VDI-Verlag, Düsseldorf, 301–314.

Heimgärtner, R. 2007. A Tool for Cross-Cultural Human Computer Interaction Analysis. In: Osswald, A., Stempfhuber, M., Wolff, C. (eds.). Proceedings of Conference Open Innovation: International Symposium for Information Science. Constance: UVK. 145-157

Heimgärtner, R., Holzinger, A. and Adams, R. 2008. From Cultural to Individual Adaptive End-User Interfaces: Helping People with Special Needs. Proceedings of Conference ICCHP, LNCS 5105, 82–89.

Hell, K., Cardwell, K.F., Setamou, M. and Poehling, H.M. 2000. The influence of storage practices on aflatoxin contamination in maize in four agroecological zones of Benin, West Africa. *Journal of Stored Product Research*, 36(4), 15 October, 365-382.

Helland I.S. 1990. PLS regression and statistical models. *Scandivian Journal of Statistics*, 17, 97–114.

Helm, S., Eggert, A. and Garnefeld, I. 2010. Modeling the impact of corporate reputation on customer satisfaction and loyalty using partial least squares. In V. Esposito, *et al*, (Eds.), *Handbook of Partial Least Squares*. Berlin: Springer, 515-534.

Henseler, J. and Fassott, G., 2010. Testing moderating effects in PLS path models: an illustration of available procedures. In V. V. Esposito, *et al*, (Eds), *Handbook of Partial Least Squares*. Berlin: Springer, 713-735.

Henseler, J., Ringle, C.M. and Sinkovics, R.R. 2009. The use of partial least squares path modeling in international marketing. In R. R. Sinkovics and P. N. Ghauri, (Eds), *Advances in International Marketing*, 20, 277–320.

Heukelman, D. 2006. Can a user centred approach to designing a user interface for rural communities be successful? Proceedings of Conference CHI-SA, Cape Town South Africa, 25-27 January, 51-58.

Heukelman, D. and Eyono Obono, S.D. 2009. Exploring the African Village metaphor for computer user interface icons. Proceedings of the 2009 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists SAICSIT '09, 132-140.

Hochberg, Y. and Tamhane, A.C. 1987. Multiple Comparison Procedures. New York: Wiley.

Hofmeester, K. and Wixon, D. 2010. Using metaphors to create a natural user interface for Microsoft surface. Proceedings of Conference CHI EA'10, 4629-4644.

Hofstede, G. 1991. Cultures and Organizations: Software of the Mind. McGraw-Hill, London.

Hoggan, E. and Brewster, S. 2007. Designing Audio and Tactile Crossmodal Icons for Mobile. Proceedings of Conference ICMI'07, 162-169. Nagoya, Aichi, Japan: ACM.

Hollingsed, T. and Novick, D.G. 2007. Usability Inspection Methods after 15 Years of Research and Practice. Proceedings of the 25th annual ACM International Conference SIGDOC, 249-255.

Hom, J. 2003. The usability methods toolbox [online]. Available: http://jthom.best. vwh.net /usability/. [Accessed June 3, 2007].

Hoskuldson, A. 1988. PLS regression methods. *Journal of Chemometrics*, 2, 211-228.

Huang, S-M., Shieh, K-K. and Chi, C-F. 2002. Factors affecting the design of computer icons, *International Journal of Industrial Ergonomics*, 29, 211-218.

Hulkko, S., Mattelmäki, T. and Virtanen, K. 2004. Mobile Probes. Proceedings of the 3rd Nordic Conference on Human-Computer Interaction NordiCHI '04 , October 23-27, Tampere, Finland, 43-51.

Hulland, J. 1999. Use of partial least squares (PLS) in strategic management research: a review of four recent studies. *Strategic Management Journal*, 20 (2), 195-204.

Hwang, Y. 2009. Investigating the role of identity and gender in technology mediated learning. *Behaviour & Information Technology*, 29 (3), 305-319.

Iqbal, R., Gatward, R. and James, A. 2005. A General Approach to Ethnographic Analysis for Systems Design. Proceedings of the International Conference on Design of Communication: Documenting and Designing for Pervasive Information, 34-40.

Isbister, K. 2011. Being Moved: Explorations of Designing Embodied Interaction. Proceedings of Conference CHI 2011, May 7–12, Vancouver, BC, Canada.

Jarrin, I., Geskus, R., Bhaskaran. K., Prins, M., Perez-Hoyos,. S., Muga, R., Herna´ndez-Aguado, I., Meyer, L., Porter, K., Del Amo, J. 2008. Gender differences in HIV progression to AIDS and death in industrialized countries: slower disease progression following HIV seroconversion in women. *American Journal of Epidemiology,* 168 (5), 532-540.

Jokela, T., Koivumaa, J. and Pirkola, J. 2006. Methods for quantitative usablity requirements: a case study on the development of the user interface of a mobile phone. *Personal Ubiquitous Computing*, 10, 345-355.

Kalra, N., Lauwers, T., Dewey, D., Stepleton, T. and Dias, M. 2007. Iterative Design of a Braille Writing Tutor to Combat Illiteracy. IFYRE program and National Science Foundation.

Keates, S., Clarkson, J. and Robinson, P. 2000. Investigating the Applicability of User Models for Motion-Impaired Users. Proceedings of Conference ASSETS'00, 129-136. Arlington, Virginia: ACM.

Kim, J. H. and Lee, K. P. 2005. Cultural Difference and Mobile Phone Interface Design: Icon Recognition According to Level of Abstraction. Proceedings of Conference MobileHCI'05, September 19-22, Salzburg, Austria.

Kirakowski, J. 2003. Questionnaires in Usability Engineering. A List of Frequently Asked Questions (3rd Ed.) [online]. Available: http://www.ucc.ie/hfrg/resources/qfaq1.html. [Accessed 12 July 2011].

Kimaro, H. C. and Titlestad, O. H. 2008. Challenges of user participation in the design of a computer based system: The possibility of participatory customisation in low income countries. *Health Informatics in Developing Countries*, 2, 1–9.

Kobsa, A. 2001. Generic Modeling in Systems. *User Modeling and User-Adapted Interactions*, 11, 49-63.

Krauss, K. 2009. The collision between international ICT policy and a deep rural Afro centric community in South Africa: assumptions, interpretation, implementation and reality. Proceedings of Second Annual Conference SIG GlobDev Workshop, December 14, Phoenix, USA.

Kuicheu, N.C., Fotso, L.P. and Siewe, F. 2007.Iconic Communication System by XML Language (SCILX). Proceedings of Conference W4A2007, 7 – 8 May 2007, Banff, Canada.

Kuo, Y.F. and Yen, S.N. 2009. Towards an understanding of the behavioral intention to use 3G mobile value-added services. *Computer Human Behavior*, 25(1), 103–110.

Kurniawan, S.H. 2000.A rule of thumb of icons' visual distinctiveness. Proceedings on the Conference on Universal Usability. Arlington, Virginia, United States: ACM Press.

LaRose, R., Gregg, J., Strover, S., Straubhaar, J and Carpenter, S. 2007. Closing the rural broadband gap: Promoting adoption of the Internet in rural America. *Telecommunications Policy*, 31, 359-373.

Li, S., Glass, R. and Records, H. 2008. The influence of gender on new technology adoption and use-mobile commerce. *Journal of Internet Commerce*, 7 (2), 270-89.

Lindberg, T., Näsänen, R. and Müller, K. 2006. How age affects the speed of perception of computer icons. Proceedings of Conference of Finish Institute of Occupational Health, 170-177. Helsinki, Finland.

Lohmoller, J. B. 1989. Latent variable path modeling with partial least squares. *Heidelberg: Physica*.

Luk, J., Pasquero, J., Little, S., MacClean, K., Levesque, V. and Hayward, V. 2006. A role for haptics in mobile interaction: initial design using a handheld tactile display prototype. Proceedings of Conference SIGCHI, 171-180, Québec, Canada: ACM

Macaulay, C., Jacucci, G., O'Neill, S., Kankaineen, T. and Simpson, M. 2006.The emerging roles of performance within HCI and interaction design. *ACM Interaction with Computers*, 18(5), 942-955.

Marcus, A. 1998. Metaphor design in user interfaces. *Journal of Computer Documentation*, 22(2), 43–57.

Martens, H. and Naes, T. 1989. Multivariate Calibration. London: Wiley.

Matthee, K.W., Mweemba, G., Pais,A.V., Van Stam, G. and Rijken, M. 2007. Bringing Internet connectivity to rural Zambia using a collaborative approach. Available: http://researchspace.csir.co.za/dspace/bitstream/10204/2858/1/Matthee_2007.pdf. [Accessed 28 May 2009].

McDonald, S., Monahan, K. and Cockton, G. 2006. Modified Contextual Design as a Field Evaluation Method. Proceedings of Conference *NordiCHI*, 437-440. Oslo, Norway: ACM.

McIntosh, A.R., Bookstein, F.L., Haxby, J.V.and Grady, C.L. 1996. Spatial pattern analysis of functional brain images using Partial Least Squares. *Neuroimage*, 3, 143–157.

McLachlan, G.J. and Basford, K.E.1988. *Mixture Models: Inference and Applications to Clustering,* New York, NY: Marcel Dekker.

Mclachlan, G. and Krishnan, T.1997. *The EM Algorithm and Extensions*, Wiley and Sons, New York.

Michie, S. and Nelson, D.L. 2006. Barriers women face in information technology careers: self-efficacy, passion and gender biases. *Women in Management Review*, 21 (1), 10–27.

Miller, G.E. 1990. The assessment of clinical skills/competence/performance. *Academic Medicine: Journal of the Association of American Medical Colleges*, 65(69), 63–67.

Miller, R. (n.d). Web Interface Design: Learning from our Past [online]. Available: http://www.cs.rutgers.edu/~shklar/www4/rmiller/rhmpaper.html [Accessed June 22, 2009].

Mishra, P. & Koehler, M. J. 2006. Technological Pedagogical Content Knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Mouton, J. 2001. *How to succeed in your Master's & Doctoral Studies.* Western Cape: Van Schaik Publishers.

Mushengyezi, A. 2003. Rethinking indigenous media: rituals, 'talking' drums and orality as forms of public communication in Uganda. *Journal of African Cultural Studies*, 16(1), June 2003, 107-117.

Nielsen, J. 1994, Usability inspection methods. Proceedings of CHI '94 Conference companion on Human factors in computing system, New York, 413-414.

Nissen, M.E. 2006. Harnessing Knowledge Dynamics: Principled Organizational Knowing and Learning. Hershey, Pennsylvania: IRM Press.

Noar, S.M. and Mehrotra, P. 2011. Toward a new methodological paradigm for testing theories of health behaviour and health behavior change. *Patient Education and Counceling*, 82(3), 468-474.

Norton, E.C., Wang, H. and Ai, C. 2004. Computing interaction effects and standard errors in logit and probit models. *Stata Journal*, 4 (2), 154-167.

Olugbara O.O. and Adebiyi A.A. 2007. Lessons from Applying XP Methodology to Business Requirements Engineering in Developing Countries Context. *International Journal of Social and Human Sciences*, 1, 438-441.

Ong, W.J. 1977. African Talking Drums and Oral Noetics. *New Literary History*: *Oral Cultures and Oral Performances*, 8(3), 411-42.

Orlikowski, W. J. 1992. Learning from Notes: Organizational Issues in Groupware Implementation. Proceedings of the Computer Supported Cooperative Work (CSCW'92): 362-369.

Oulasvirta, A., Kurvinen, E. and Kankainen, T. 2003. Understanding contexts by being there: case studies in bodystorming. *Personal Ubiquitous Computing*, 7(2), 125-134.

Pade, C., Mallinson, B. and Sewry, D. 2006. An exploration of the Categories Associated with ICT Project sustainability in Rural Areas of Developing countries: A Case study of the Dwesa Project. Proceedings of Conference *SAICSIT*, 100-106.

Pages, J. and Tenenhaus, M. 2001. Multiple factor analysis combined with PLS path modeling. Application to the analysis of relationships between physicochemical variables, sensory profiles and hedonic judgments. *Chemometrics and Intelligent Laboratory Systems*, 58, 261–273.

Pahnila, S. and Warsta, J. 2010. Online shopping viewed from a habit and value perspective. *Behaviour & Information Technology*, 29 (6)**,** 621-632.

Parikh, T., Ghosh, K. and Chavan, A. 2003. Design Studies for a Financial Management System for Micro-Credit Groups in Rural India [online], Available: http://www.cs. washington.edu/homes/tapan/papers/p0314-parikh.pdf. [Accessed November 28, 2007].

Parikh, T.S. and Lazowski, E.D. 2006. Designing an Architecture for Delivering Mobile Information Services to the rural developing world. Proceedings of International World Wide Web Conference (IW3C2), 791-800.

Patel, S., Bataveljic, O., Lisboa, P.J., Hawkins, C. and Rajan, R. 2006. iShakti – Crossing the Digital Divide in Rural India. Proceedings of IEEE/WIC/ACM International Conference on Web Intelligence, IEEE.

Payne, P.R.O. and Starren, J. 2006. Presentation Discovery: Building a better icon. Proceedings of Conference CHI, April 22-27, Montréal, Québec, Canada.

Poli, R. and Vali, G. 1997. An algorithm for real-time vessel enhancement and detection. *Computer Methods and Programs in Biomedicine*, 52(1), January, 1-22.

Polson, P., Lewis, C., Rieman, J. and Wharton, C. 1992. Cognitive walkthroughs: A method for theory-based evaluation of user interfaces. *International Journal of Man-Machine Studies*, 36, 5, 741-773.

Pringle, I. and David, M. 2002. Rural Community ICT Applications: The Kothmale Model. *The Electronic Journal on Information Systems in Developing Countries* , 1-14.

Qiu, Y., Yu, P. and Hyland, P.A. 2007. Multi-method approach to assessing Health Information Systems end users' training needs. Proceedings of the 12th World Congress on Health (Medical) Informatics; Building Sustainable Health Systems, 1352-1356.

Ramachandran, D., Kam, M., Chui, J., Canny, J. and Frankel, J. 2007. Social Dynamics of Early Stage Co-Design in Developoing Regions. Proceedings of Conference CHI, 1087-1850. San Jose, California, USA: ACM.

Ramaswamy, V., De Sarbo, W.S., Reibstein, D.J. and Robinson, W.T. 1993. An Empirical Pooling Approach for Estimating Marketing Mix Elasticities with PIMS Data. *Marketing Science*, 12(1), 103-124.

Rao, S.S. 2005. Bridging Digital Divide: Efforts in India. *Telematics and Informatics*, 22(4), 361-375.

Raykov, T. 2011. Evaluation of convergent and discriminant validity with multitrait–multimethod correlations. *British Journal of Mathematical and Statistical Psychology*, 64 (1)**,** 38-52.

Reschly, D. J. 1990. Found: our intelligences: what do they mean? *Journal of Psycho educational Assessment*, 8,259–267.

Richards, F. and Van Belle, J.P. 2006. Determinants of 3G Mobile Video Adoption by the South African Mobile Consumer. Proceedings of IRMA International Conference, Washington DC.

Rigdon, E.E., Ringle, C.M. and Sarstedt, M. 2010. Structural modeling of heterogeneous data with partial least squares. *Review of Marketing Research*, 7(7), 255-296.

Ringle, C.M. Sarstedt, M. and Mooi, E.A. 2010. Response-based segmentation using finite mixture partial least squares: Theoretical foundations and an application to American customer satisfaction index data. *Annals of Information Systems*, 8, R. Stahlbock. S.F. Crone and S. Lessmann (Eds.), Springer, NewYork, Dordrecht Heidelberg, London. 14–52.

Ringle, C. M., Wende, S. and Will, A. 2005. Customer Segmentation with FIMIX-PLS, in Thomàs Aluja, Josep Casanovas, Vincenzo Esposito Vinzi, Alain Morrineau and Michel Tenenhaus (Eds.), PLS and Related Methods – Proceedings of the PLS'05 International Symposium, Paris: Decisia, 507-514.

Romm, C. and Taylor, W. 2001. The Role of Local Government in Community Informatics Success Prospects: The Autonomy/Harmony Model. Proceedings of Conference on System Sciences, 1-8. Hawaii: IEEE.

Rose, A., Shneiderman, B. and Plaissant, C. 1995. An applied ethnographic method for redesigning user interfaces. Proceedings of the 1st Conference on Designing Interactive Systems: processes, practices, methods and techniques, 115-122.

Röse, K., Liu, L. and Zühlke, D. 2001. Design Issues in Mainland China: Demands for a Localized Human-Machine-Interaction Design. In: Johannsen, G. (ed.) 8th IFAC/IFIPS/IFORS/IEA Symposium on Analysis, Design and Evaluation of Human-Machine Systems, Preprints Kassel, 17–22.

Rubin, J. 1994. *Handbook of usability testing: how to plan, design and conduct effective tests.* New York, NY: Wiley.

Sakai, T. 2007. Evaluating information retrieval metrics based on bootstrap hypothesis tests. *IPSJ Digital Courier*, 3, 625-642.

Sarstedt, M. (2008). A Review of Recent Approaches for Capturing Heterogeneity in Partial Least Squares Path Modelling, *Journal of Modelling in Management* 3, 140-161.

Sarstedt, M. and Ringle, C.M. 2010. Treating unobserved heterogeneity in PLS path modeling: A comparison of FIMIX-PLS with different data analysis strategies. *Journal of Applied Statistics*, 37(8), 1299-1318.

Sarstedt, M., Ringle, C.M. and Schwaiger, M. 2009. Do we fully understand the critical success factors of customer satisfaction with industrial goods? Extending Festge and Schwaiger's model to account for unobserved heterogeneity. *Journal of Business Market Management*, 3(3), 185-206.

Sarstedt, M., Becker, J., Ringle, C.M. and Schwaiger, M. 2011. Uncovering and Treating Unobserved Heterogeneity with FIMIX-PLS: Which Model Selection Criterion Provides an Appropriate Number of Segments? Unobserved Heterogeneity, sbr 63 January, 34-62.

Sattar, K. 2007. A sustainable model for use of ICTs in rural Pakistan. *International Journal of Education and Development using Information and Communication Technology*, 3(2), 116-124.

Schleicher, D., Jones, P. and Kachur, O. 2010. Bodystorming as embodied designing. *Interactions*, 17(6), November + December, 47-51.

Schwarz, G. 1978. Estimating the Dimension of a Model. *The Annals of Statistics*, 6(2), 461-464.

Schwartzman, Y. and Parikh, T. 2007. Establishing Relationships for Designing Rural Information Systems. Proceedings of Conference CHI, 1845-1850. San Jose, CA, USA: ACM.

Schwartzman, Y. and Parikh, T.S. 2007. Using CAM-equipped Mobile Phones for Procurement and Quality Control at a Rural Coffee Cooperative. Proceedings of Conference WWW2007, May 8–12, Banff, Canada.

Selwyn, N. 2006. Digital division or digital decision? A study of non-users and low-users of computers. *Poetics*, 34(4-5), 273-292.

Sharp, H., Rogers, Y. and Preece, J. 2006. *Interaction Design: Beyond human-computer interaction*. John Wiley and Sons: West Sussex, U.K., 236-237.

Sheeran, P. 2002. Intention-behavior relations: a conceptual and empirical review. *In* W. Stroebe, *et al*, (Ed.) *European Review of Social Psychology*. Chichester, UK: Wiley, 1-36.

Shen, T.S, Woolley, M. and Prior, S. 2006. Towards culture-centred design. *ACM Interacting with Computers*, 18, 820-852.

Sheppard, C. and Scholtz, J. 1999. The Effects of Cultural Markers on Website Use. Proceedings of Conference on Human Factors and the Web, Gaithersburg, USA, June.

Singh, M., Mandal, M.K. and Basu, A. 2005. Gaussian and Laplacian of Gaussian weighting functions for robust feature based tracking. *Pattern Recognition Letters*, 26(13), 1995-2005, ACM.

Singh, S. and Shinde, D. 2004. Stakeholder Partnerships for ICT in Rural Communities [online]. Available: http://www.adbi.org/conf-seminar-papers/2005/03/14/926. stakeholder.ict.paper. [Accessed February 23, 2006]

Smith, S. 1996. Flexible filter neighbourhood designation. Proceedings of 13th International Conference on Pattern Recognition, 206-212.

Sobel, M. E.1982. Asymptotic confidence intervals for indirect effects in structural equation models. *Social Methodology*, 13, 290-312.

Soriano, C.R.R. 2007. Exploring the ICT and Rural Poverty Reduction Link: Community Telecenters and Rural Livelihoods in Wu an, China. EJISDC. 32(1), 1-15.

Straub, D.,Loch, K., Evaristo, R., Karahanna, E. and Strite, M. 2002. Toward a Theory-Based Measurement of Culture. *Journal of Global Information Management*, 10(1), 13-23.

Stoecker, R. 2005. Is Community Informatics good for communities? *The Journal of Community Informatics* , 1(3), 13-26.

Struwig, F.W. and Stead, G.B. 2001. *Planning, designing and reporting research*. Cape Town: Pearson Education South Africa.

Sun, H. and Zhang, P. 2006. The role of moderating factors in user technology acceptance. *International Journal of Human-Computer Studies*, 64 (2), 53-78.

Tamari, T. 1991. The Development of Caste Systems in West Africa. *The Journal of African History*, 32(2), 221-250

Tedre, M., Sutinen, E., Kähkönen, E. and Kommers, P. 2006. Ethnocomputing: ICT in cultural and social context. *Communications of ACM* , January, 126-130.

Tenenhaus, M. 1998. La regression PLS, Theorie et Pratique. Technip, Paris.

Tenenhaus, M, Amato, S and Vinzi, V.E. 2004. A global goodness-of-fit index for PLS structural equation modelling. Proceedings of the XLII Società Italiana di Statistica (SIS) Scientific Meeting, CLEUP, Padova, Italy, 739–742.

Tenenhaus, M., Vinzi, V. E., Chatelin, Y.-M. and Lauro, C. 2005. PLS path modelling. *Computational Statistics and Data Analysis*, 48, 159–205.

Terada, M. 2010. E-business piloting and readiness for rural women weavers in Bhutan: lessons learned [online]. Available: http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan046031.pdf. [Accessed 2 September 2011].

Thompson, K.E., Rozanski, E.P. and Haake, A.R. 2004. Here, there, anywhere: remote usability testing that works. Proceedings of the 5th Conference on Information Technology EducationCITC5, 132 – 137.

Thompson, S.S., Miller, K.B. and Lopez, A.S. 2001. Cocoa and Coffee, in Food Microbiology, ed. Doyle, M.P., Beuchat, L.R. and Montville, T.J. *Food Microbiology*, ASM Press, New York.

UN. Millennium Project Commissioned by the UN, 2006. [online], Available: http://www.unmillenniumproject.org/goals/gti.htm. [Accessed 15 January 2009].

UNCTAD. 2001. The World Investment Report.

UNESCO. 2008. Policy Framework: ICT Competency Standards for Teachers. Available: http://cst.unesco-ci.org/sites/projects/cst/The%20Standards/ICT-CST-Policy%20Framework.pdf [Accessed 6 June 2012].

UsabilityNet. 2002. Promoting Usability and User Centred Design in European Industry [online]. Available: http://www.usability.org/ management/b_design.htm, [Accessed October 3, 2005].

Väänänen-Vainio-Mattila, K., VirpiRoto,V. and Hassenzahl, M. 2008.Towards Practical User Experience Evaluation Methods. 5th COST294-MAUSE Open Workshop on Valid Useful User Experience Measurement.

Vanderwooda, M.L., McGrewb, K.S., Flanaganc, D.P. and Keithd, T.Z. 2002. The contribution of general and specific cognitive abilities to reading achievement. *Learning and Individual Differences*, 13, 159–188.

Vasilyeva, E., Pechenizkiy, M. and Puuronen, S. 2005. Towards the Framework of Adaptive User Interfaces for eHealth. Proceedings of the 18th IEEE Symposium on Computer-Based Medical Systems, 1053-7125.

Venkatesh, V. and Davis, F. D., 2000. A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management Science*, 46(2), 186–204.

Venkatesh, V. Morris, M.G., Davis, G.B. and Davis, F.D. 2003. User acceptance of information technology: toward a unified view. *MIS Quarterly*, 27 (3), 425-478.

Vincenzo, E.V., Chatelin, Y. and Tenenhaus, M. 2002. State-of-art on PLS Path Modeling through the available Software. In: HEC Research Papers Series n.764/2002, HEC School of Business and Management. Jouy-en-josas (France): HEC Research Papers Series.

Vinzi, V.E., Trinchera, L and Amato, S. 2010. PLS Path Modeling: From Foundations to Recent Developments and Open Issues for Model Assessment and Improvement. V. Esposito Vinzi et al. (Eds.), *Handbook of Partial Least Squares*, Springer Handbooks of Computational Statistics, 47-82.

Wade, R.H. 2002. Bridging the Digital Divide: New Route to Development or New Form of Dependency? *Global Governance*, 8(4), 443, 24p.

Wang, H. 2007. Are Icons Used in Existing Computer Interfaces Obstacles to Taiwanese Computer Users? Proceedings European Conference on Cognitive Ergonomics, 199-202, London, UK: ACM.

Wang, H., Hung, S. and Liao, C. 2007. A survey of Icon Taxonomy Used in the Interface Design. Proceedings of Conference *ECCE*, 203-206. London, UK.

Wedel, M. and Kamakura, W.A. 2000. Market Segmentation: Conceptual and Methodological Foundations, 2nd ed., Kluwer Academic Publishers, Boston.

Welsh, J.A., Nix, R.L., Karen, C.B., Bierman,L. and Nelson, K.E. 2010. The Development of Cognitive Skills and Gains in Academic School Readiness for Children from Low-Income Families. *Journal Educational Psychology*, February, 102(1), 43–53.

Wertz, C., Linn, R. and J¨oreskog, K. 1974. Intraclass reliability estimates: Testing structural assumptions. *Educational and Psychological Measurement, 34*(1), 25–33.

Wold, H. 1966. Estimation of principal components and related models byiterative least squares. In Krishnaiah, P.R (Ed.), Multivariate Analysis, 391-420. New York: Academic Press.

Wold, H. 1973. Non-linear iterative partial least squares (NIPALS) modelling. Some current developments. In Krishnaiah, P.R. (Ed.), Multivariate Analysis, Vol. III. Academic Press, New York. 383-407.

Wold, H. 1974. Causal Flows with Latent Variables: Partings of Ways in the Light of NIPALS modelling. *European Economic Review, 5*(1), 67-86.

Wold, H. 1975. Soft modelling by latent variables: the non-linear iterative partial least squares (NIPALS) approach. In Gani, J. (Ed.), Perspectives in Probability and Statistics: Papers, in Honour of M.S. Bartlett on the Occasion of his Sixty-8fth Birthday. Applied Probability Trust, Academic, London. 117-142.

Wold, H. 1982. Soft modeling, the basic design and some extensions. In K. G. Jreskog and H. Wold (Eds.), Systems under indirect observation, I–II. Amsterdam: North-Holland.

Wong, P.K. 2002. ICT production and diffusion in Asia Digital dividends or digital divide? *Information Economics and Policy*, 14(2), 167-187.

Xie, A., Rau,P.L.P., Tseng, Y., Su, H. and Zha, C. 2009. Cross-cultural influence on communication effectiveness and user interface design. *Journal of Intercultural Relations, 33(1), 11-20.*

Xing, G., Li, Z., Wang, X. and Guo, L.2010. A model of university teaching teacher's competence evaluation based on information entropy and unascertained measure. Chinese Control and Decision Conference. 438-441.

Yang, H., Han, S.H. and Park, J. 2010. User interface metaphors for a PDA operating system. *International Journal of Industrial Ergonomics*, 40(5), 517-529.

Yang, H., Griffiths, P.R. and Tate, J.D. 2003. Comparison of Partial Least Squares regression and multi-layer neural networks for quantification of nonlinear systems and application to gas phase Fourier transform infrared spectra. *Analytica Chimica Acta,* 489, 125–136.

Young, P. 2008. Integrating Culture in the Design of ICTs. *British Journal of Educational Technology*, 39(1), 6–17.

Zajicek, M. 2001. Interface design for older adults. WUAUC'01 Proceedings of the 2001 EC/NSF workshop on Universal accessibility of ubiquitous computing: providing for the elderly, 60-65, ACM New York.

Zhang J. and Norman, D.A. 1994. Representations in distributed cognitive tasks. *Cognitive Science*, 18, 87–122.

Zhao, L. and Thorpe, C.E. 2000. Stereo- and Neural Network-Based Pedestrian Detection. IEEE *Transactions On Intelligent Transportation Systems*, September, 1(3), 148-154.

Appendix A PLS Tutorial

The PLS regression procedure (Wold, 1973; Wold, 1974; Wold, 1975) establishes a first order relationship between exogenous (independent) construct x and endogenous (dependent) construct y by two sets of linear systems of equations called inner model and outer model. The latent and manifest variables are standardized to discard the location parameters. The basic PLS design assumes recursive inner model linking LVs as follows:

$$y = \beta y + \alpha x + \zeta \quad \text{(A.1)}$$

Where y symbolizes a matrix of dimension (g x n), x is a matrix of dimension (h x n), n denotes the number of cases, β is a coefficient matrix of dimension (g x g), α is a coefficient matrix of dimension (g x h) and ζ denotes an inner model residuals matrix of dimension (g x n).

The outer model equation for endogenous LVs is given as follows:

$$z = \pi y + e \quad \text{(A.2)}$$

Where z symbolizes an (m x n) dimensional matrix of MVs related to the LVs by the coefficients given by an (m x g) dimensional matrix π and e denotes the associated (m x n) dimensional matrix of outer model residuals. The inner model given by equation (A.1) is used to substitute the endogenous LVs in the outer model given by equation (A.2) to obtain the Wold substitutive elimination result:

$$z = \pi(\beta y + \alpha x) + \pi\zeta + e \quad \text{(A.3)}$$

A1. Model Estimation

The individual model item reliability is the extent to which the measurements of factors measured with multiple-item scale reflects the true score of the constructs relative to the error (Hulland, 1999; Aibinu and Al-Lawati, 2010). Cronbach's alpha (Cronbach, 1951) and Dillon-Goldstein or Joreskoz's rho (Wertz, 1974; Tenenhaus et al., 2005) have suggested that if the block of MVs negatively correlated with the first principal component, the MVs are inadequate to measure the LVs and they should be removed from the outer model.

The internal consistency of a construct estimates how consistently individuals respond to the items within a scale (Shin, 2009). It is determined in terms of the correlation metric as:

$$\alpha = \frac{p}{p-1}\left(\frac{\sum_{i\neq j} cor(x_i, x_j)}{P+\sum_{i\neq j} cor(x_i, x_j)}\right) \quad (A.4)$$

The Dillon-Goldstein's rho (ρ), which is sometimes called a composite reliability, is a measure of the overall reliability of similar items (Roca et al. 2009; Henseler et al., 2009). This statistic is considered to be a better indicator of the homogeneity than Cronbach's alpha (Chin, 1998). The Dillon-Goldstein's rho is estimated as (Vinzi et al., 2010):

$$\rho = \frac{\left(\sum_{h=1}^{p} cor(x_{jh}, t_1)\right)^2}{\left(\sum_{h=1}^{p} cor(x_{jh}, t_1)\right)^2 + \sum_{h=1}^{p}\left(1-cor^2(x_{jh}, t_1)\right)} \quad (A.5)$$

There are three schemes available in the literature for obtaining inner weights, which are centroid (Wold, 1973), factorial (Lohmoller, 1987) and path weighting (Vincenzo et al., 2002). The structural model is given by the regression equation on non-centred latent variable $\hat{\xi}$ as follows.

$$\hat{\xi}_j = \beta_{j0} + \sum_i \beta_{ji}\hat{\xi}_i + \upsilon_j \quad (A.6)$$

The generic coefficient β_{ji} is the regression coefficient, which is also called the loading and it corresponds to the correlation between the manifest and latent variables when the manifest variables are standardized, υ_j is the residual and the location parameter β_{j0} is the constant/intercept for endogenous latent variable (for standardize manifest variables, it is 0). The location parameter is given in terms of mean $\hat{m}_j$ for exogenous latent variable as follows:

$$\beta_{j0} = \hat{m}_j - \sum_i \beta_{ji}\hat{m}_i \quad (A.7)$$

The structural equations modelling of the TSM are therefore described as follows:

Comprehension = β_{20} + β_{21} Knowledge + ν_2

Skills = β_{30} + β_{31} Knowledge + β_{32} Comprehension + ν_3 (A.8)

Performance = β_{40} + β_{41} Knowledge + β_{42} Comprehension + β_{43} Skills + ν_4

Support = β_{50} + β_{51} Knowledge + β_{52} Comprehension + β_{54} Performance + ν_5

The convergent validity is measured by Average Variance Expected (AVE) and is calculated from the outer loading of an item λ_i (Henseler et al., 2009):

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum (1-\lambda_i^2)} \tag{A.9}$$

The Pearson product moment correlation r between factors x and y with means $\bar{x}$ and $\bar{y}$ respectively is calculated as (Spiegel, 1972):

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 (y_i - \bar{y})^2}} \tag{A.10}$$

The communality index measures how much of the MVs variability is explained by own LV scores and is defined for j block as:

$$CI_j = \frac{1}{p_j} \sum_{h=1}^{p_j} cor^2(x_{jh}, \hat{\xi}_j), \forall j : p_j > 1 \tag{A.11}$$

The mean communality is the average of all the squared correlations between each MV and the corresponding LV scores in the model and is defined as:

$$\overline{CI_j} = \frac{1}{p} \sum p_j CI_j \tag{A.12}$$

where p is the total number of MVs in all blocks. The quality of the inner model for each endogenous block taking into account the outer model is measured by the Redundancy Index (RI), which is defined for an endogenous block j as:

$$RI_j = CI_j \times R^2(\hat{\xi}_j, \hat{\xi}_i) \tag{A.13}$$

The coefficient of determination (R^2) is the amount of variance in a dependent factor that is explained by the model (Cornell and Berger, 1987). The R^2 value is computed as follows (Tenenhaus et al., 2005):

$$R^2 = \sum_j \hat{\beta}_j cor(y, x_j) \tag{A.14}$$

where x_j is the value of the exogenous variable at which y is observed. The R^2 values of 0.67, 0.33 and 0.19 are considered to be substantial, moderate and weak respectively (Chin, 1998). In addition, R^2 values can be analysed using F-test to determine whether they are statistically significant from zero as (Aibinu and Al-Lawati, 2010):

$$F_R = \frac{R^2(N-M-1)}{M(1-R^2)} \quad \text{(A.15)}$$

where N is sample size, M is the number of independent factors and M and (N-M-1) are degrees of freedom. The R^2 fit index can be used to measure the quality of each structural equation, but it is insufficient to evaluate the whole inner model because it only takes into account the fit of each regression equation in the inner model.

The GoF index is a global criterion calculated as the geometric mean of the average communality index (CI) and the average R^2 value (Chin, 2010):

$$GoF = \sqrt{CI \times R^2} \quad \text{(A.16)}$$

The value of Q^2 is calculated in terms of the ratio of the sum of the squared prediction error to the sum of squares of observations as:

$$Q^2 = 1 - \frac{\sum_i (x_{ji} - \overline{x_j} - \hat{\pi}_j Y_{ji})^2}{\sum_i (x_{ji} - \overline{x_j})^2} \quad \text{(A.17)}$$

A2. Interaction Effects

The test for moderating effect can be assessed by determining its strength or effect size and then testing for its significance. The effect size f^2 is calculated in terms of $R^2(i)$ with moderating effect and $R^2(e)$ with main effect as (Helm et al., 2010):

$$f^2 = \frac{R^2(i) - R^2(e)}{1 - R^2(i)} \quad \text{(A.18)}$$

The effect size is considered large, medium and small if greater than 0.35, 0.15 and 0.02 respectively (Cohen, 1988). The significance of the effect size is tested using the F-test as (Aibinu and Al-Lawati, 2010):

$$F_f = (f^2)(N - M - 1) \quad \text{(A.19)}$$

The test for significance can be performed using z-statistics (z) defined as (Sobel, 1982):

$$z = \frac{a * b}{\sqrt{b^2 * s_a^2 + a^2 * s_b^2}} \quad \text{(A.20)}$$

The mediation effect size can be estimated using the Variance Accounted For (VAF) that represents the ratio of interaction effect to main effect. VAF is computed for the path coefficient c of a direct relationship from F1 to F2 and path coefficients a, b as (Helm et al., 2010):

$$VAF = \frac{a * b}{a * b + c} \quad \text{(A.21)}$$

A3. Paths Comparison

The difference between the estimators of path models are tested for significance with a t-test as follows (Chin, 2000):

$$t = \frac{Path_{sample1} - Path_{sample2}}{\sqrt{\left[\frac{(m-1)^2}{(m+n-2)} * S.e^2._{sample1} + \frac{(m-1)^2}{(m+n-2)} * S.e^2._{sample2}\right]} * \left[\sqrt{\frac{1}{m} + \frac{1}{n}}\right]} \quad \text{(A.22)}$$

where:

Path sample1/2 is the original sample estimate for the path coefficient in both subsamples respectively, M is the number of cases in sample 1, N is the number of cases in sample 2, S.e.sample1/2 is the standard error of the path coefficient in both subsamples respectively.

A4. Path Model Segmentation

The FIMIX-PLS calculates the probability of each of the predetermined K number of segments. The mixing proportion π_k determines the relative size of segments k (k=1, 2,...,K) with each $\pi_k > 0$ positive and all π_k summing to unity. The segment specific distribution function is defined, assuming that each endogenous LV η_i is distributed as a finite mixture of conditional multivariate normal densities f_{ik} as (Sarstedt and Ringle, 2009; Sarstedt et al., 2011):

$$\eta_i = \sum_{k=1}^{K} \pi_k \left(\frac{|B_k|}{(2\pi)^{M/2} \sqrt{|\psi_k|}} \right) \exp\left(-\frac{1}{2} (B_k \eta_i + \Gamma_i \xi_i)' \psi_k^{-1} (B_k \eta_i + \Gamma_i \xi_i) \right) \quad \text{(A.23)}$$

where ξ_i is an exogenous variable vector in the inner model in respect of observation i, B_k is the path coefficient matrix of the endogenous variable and Γ_k of the exogenous LVs,

ψ_k is the matrix of each segment regression variances of the inner model on the diagonal and zero else and M is the number of endogenous LVs in the inner model.

The EN criterion indicates the degree of all observations' classification and their estimated segment membership probabilities P_{ik}. It reveals the most appropriate number of latent segments for a clear-cut FIMIX-PLS segmentation:

$$EN_k = 1 - \frac{\left(\sum_{i=1}^{I} \sum_{k=1}^{K} - P_{ik} \ln(P_{ik}) \right)}{I \ln(K)} \tag{A.24}$$

The EN ranges between 0 and 1, wherein the quality of the classification commensurate with the increase in EN_k.

Appendix B Sample Data

This section publishes the statistical data that was used for the PLS and FIMIX-PLS experimentations. Interested users can experiment with the data, but the source must be acknowledged. The item CU indicates Culture, KN2, KN3, KN4 are high loading items that measure user knowledge. CM3, CM4, CM5 measure user comprehension, SK3, SK5 measure user skills, PM1, PM2, PM4 measure user performance and SP1, SP2, SP4, SP5 measure user support. The FIMIX-PLS segmentation algorithm detected three segments that characterize heterogeneity. In data table below, Segment 1 contains the first 24 cases, Segment 2 contains the next 33 cases and Segment 3 contains the last 14 cases. In Segment 1 there are 12 Blacks who share similar beliefs on user support for alternative African village metaphors as user interface icons with 1 White/Coloured and 11 Indians. In Segment 2 there are 11 Blacks who share similar beliefs with 5 White/Coloured and 17 Indians. In Segment 3 there are 7 Blacks who share similar beliefs with 1 White/Coloured and 6 Indians. It should be observed that items that reported low loadings or have not contributed to characterizing heterogeneity in dataset are excluded in the table.

CU	KN 2	KN 3	KN 4	CM 3	CM 4	CM 5	SK 3	SK 5	PM 1	PM 2	PM 4	SP 1	SP 2	SP 4	SP 5
2	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
1	1	1	1	0	1	1	0	1	1	1	1	0	0	0	0
1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
3	1	1	1	0	1	0	0	1	1	1	1	1	0	1	1
3	1	1	1	0	1	0	0	1	1	1	1	1	0	1	1
3	0	1	0	1	0	0	0	0	1	1	1	1	0	0	1
3	1	0	1	0	1	1	0	1	1	1	1	1	1	0	1
3	1	0	0	0	0	1	0	0	1	1	0	1	1	0	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
1	0	1	0	1	0	0	1	0	1	0	1	0	0	0	1
3	1	1	0	0	0	1	0	0	1	1	1	1	1	0	1
3	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1
1	1	0	1	0	1	0	0	0	1	1	0	1	1	0	1

1	1	1	0	0	1	1	0	1	0	1	0	0	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1
1	0	0	1	0	1	0	0	1	1	1	1	1	1	0	1
1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	1
3	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1
1	1	1	1	1	0	0	0	0	1	1	1	0	0	0	0
1	1	1	1	0	1	0	0	0	1	1	1	1	0	1	0
1	1	1	1	1	1	0	1	1	1	0	1	0	0	0	0
1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
3	1	0	1	0	1	1	0	0	1	1	1	0	1	1	1
3	1	0	1	0	1	1	0	0	1	1	1	1	1	1	1
3	1	1	1	0	1	0	0	1	1	1	0	1	1	1	1
3	1	0	1	0	0	1	0	0	1	0	1	1	1	1	1
3	1	0	1	0	1	1	0	0	1	1	1	1	1	1	1
3	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1
3	0	0	1	0	1	0	0	1	1	1	1	1	0	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
3	1	0	1	0	1	1	0	0	1	1	0	1	1	1	1
3	1	0	0	0	0	1	0	0	1	1	1	1	0	1	1
2	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1
3	1	1	1	0	0	0	0	0	1	1	1	0	1	1	1
2	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1
2	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1
2	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1
1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1
1	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1
3	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1
1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1
3	1	1	1	0	1	0	1	1	1	0	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	0	0	1	1	0	1	0	1	0	1	1	1
3	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1
3	1	1	1	0	1	0	0	0	1	1	1	1	1	1	1
1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1
3	1	0	1	0	0	1	0	0	1	1	0	0	0	1	1

1	1	1	0	0	1	0	0	0	1	1	1	1	1	0	1
1	1	0	0	0	0	1	0	0	1	1	1	1	1	1	1
1	1	0	1	0	1	0	0	0	1	0	0	1	0	1	1
1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1
2	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1
3	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1
3	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1
3	0	0	0	0	1	1	0	1	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
3	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1
3	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1
3	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1
1	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1
1	1	1	1	0	0	0	0	0	1	1	1	0	0	1	1
1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0
1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1
1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1