

Design of a Mobile Support and Content Authoring tool to Support Deaf Adults Training in Computer Literacy Skills

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Department of Computer Science
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Dedicated to

My family

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Abstract

This dissertation investigates the challenges that Deaf adults encounter at the task of learning computer literacy skills. Deaf adults who communicate using South African Sign Language (SASL) come from poor socio-economic backgrounds are not familiar with the written form of English. They rely on interpreters and Deaf teachers to translate written text into SASL for them to learn computer literacy skill.

We present our theme of support, in which Deaf people learn via an intermediary, a teacher or facilitator, in intermediated supported learning. We propose a shift from intermediated supported learning to multimedia supported learning which is most appropriate for the context.

Using Community-based co-design we implement two systems: an authoring tool to support lesson content creation by the teacher and a mobile prototype that uses sign language videos to provide computer literacy instruction. We evaluate the two systems to evaluate if they support multimedia-supported learning.

The authoring tool allowed the facilitator create tailored lessons for the Deaf learners using pre-recorded SASL videos and images. The Deaf learners demonstrated ability to do self-paced learning while using the mobile system, better suited to Deaf learners with basic exposure to computer literacy skills.

Declaration

The work in this dissertation is based on research carried out at the Centre in Information and Communication Technology for Development (ICT4D), the Department of Computer Science, The University of Cape Town. No part of this thesis has been submitted elsewhere for any other degree or qualification and it is all my own work unless referenced to the contrary in the text. I hereby declare that this written work I have submitted is original work which I alone have authored and which is written in my own words. With the signature I declare that I have being informed regarding normal academic citation rules and I conform to citation conventions customary to the sciences. This written work may be tested electronically for plagiarism.

George G. Ng'ethe

10-2-2016

Signature

Date

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Publications

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2. Ng'ethe, G., Blake, E. and Glaser, M. (2015). SignSupport: A Mobile Aid for Deaf People Learning Computer Literacy Skills. *In Proceedings of the 7th International Conference on Computer Supported Education (CSEDU 2015 - Volume 2)*, pages 501-511.
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Glossary

API	Application Programming interface
ASL	American Sign Language
BSL	British Sign Language
LIS	Italian Sign Language
LSC	Catalan Sign Language
SL	Signed Language
DCCT	Deaf Community of Cape Town
AR	Action Research
CBCD	Community-based Co-design
DELE	Deaf-Centred Learning Environments
ICT4D	Information Communication Technology 4 Development
ICDL	International Computer Driving Licence
ECDL	European Computer Driving Licence
ECDL-F	European Computer Driving Licence Foundation
CEPIS	Council of European Professional Informatics Societies
QTB	Question and Test base
MPEG	Motion Picture Experts Group
TTY	Teletype
ITU	International Telecommunication Union
QCIF	Quarter Common Intermediate Format
CIF	Common Intermediate Format
SQCIF	Sub Quarter Common Intermediate Format
IT	Information Technology

ICT	Information and Communication Technology
SASL	South African Sign Language
TESSA	Text and Sign Support Assistant
UCD	User Centred Design
HD	High Definition
SD	Standard Definition
NGO	Non-governmental organization
ROI	Region of interest
UCT	University of Cape Town
UWC	University of Western Cape

Chapter 1

Introduction

In this dissertation we investigate the challenges Deaf adults encounter while acquiring computer literacy skills. We then consider how to support the acquisition of these skills.

Deaf adults who are functionally illiterate are dependent on intermediated learning through an intermediary (a teacher or an interpreter) to learn computer literacy skills. The lesson content – in English text – is not available in their first language, South African Sign language (SASL), which it inhibits access and support for self-paced learning. Teachers of the Deaf have to translate the lesson content into SASL and appropriate the content to the literacy levels of the Deaf adults which is a demanding task. We explore this issue in our *Support* theme detailed in Section 1.5.

We designed and evaluated systems to support the learning of computer literacy skills in collaboration with an non-governmental organisation (NGO), Deaf Community of Cape Town (DCCT), to run a computer literacy training programme at their premises in Cape Town. Our system is composed of a content authoring tool and a mobile application to allow a Deaf learner to teach themselves computer literacy skills.

1.1 Deafness, Poverty and Empowerment

Deafness is universally regarded as a physical disability, often classified along with blindness and other physical disabilities [9]. This an ambiguous situation for the Deaf

with regard to disability. Deaf people regard themselves as a minority culture. They are users of a natural signed language (South African Sign Language (SASL) in South Africa) which is not accorded the same rights as users of other languages such as English and isiXhosa [9]. To some extent, SASL has been recognised constitutionally. The Constitution of the Republic of South African [79] identifies a total of 11 official languages of which SASL is not one. Despite its lack of official language status, SASL is directly mentioned in the Constitution. The *Pan South African Language Board* (PANSALB) created under the Constitution in Chapter 1(6)5 was empowered to “promote and create conditions for, the development of all (i) official languages, (ii) the Khoi Nama and San languages and (iii) sign language” [78]. SASL has the status of a minority language. Therefore, we write Deaf with a capital ‘D’ to signify their cultural identity.

Concepts of deafness generally refer to pathological deafness represented by ‘d’ in ‘deaf’ and sociocultural deafness represented by ‘D’ in ‘Deaf’ [61]. Pathological deafness refers to deafness from a hearing loss. Sociocultural Deafness refers to a culture, social and political claims based on an ethnically Deaf identity. When one refers to pathological and cultural forms of deafness simultaneously such as a deaf person who is also culturally Deaf, the term d/Deaf can be used [61].

There exists three levels of social segmentation. They are “deaf community”, the “Deaf culture” and the “Deaf ethnicity”. The three terms identify, sometimes overlapping groups of people. [61] The “deaf community” is the broadest and inclusive grouping including anyone interested in Deaf issues. It includes members of the Deaf culture and Deaf ethnicity. Membership in this group may include hearing and d/Deaf who do not necessarily belong to Deaf culture and Deaf ethnicity [61]. Deaf culture includes both Deaf and hearing people who follow the behavioural rules of the culture and consider themselves part of the cultural group. Deaf ethnicity is an exclusive grouping with members’ identity coming from birth as a Deaf person or birth into a Deaf family (as either hearing or deaf themselves). The issue of “deaf versus hearing” is more about language fluency rather than cultural awareness and fit [61]. Culture and language issues are not distinct but are aligned along a continuum. It is important to note the Deaf community self-identity as a community and

distinct culture [8, 59].

Signed languages have phonological, syntactic and semantic levels of representation, exactly the same as any other human language. The distinguishing factor is that they are made through the medium of space and that they use the hands, face and upper torso for their realisation [8]. Signed languages are not universal and not written down. This probably leads to a slightly higher degree of variability in the signed language of a community [8].

In sub-Saharan Africa, in the face of widespread poverty, scarcity of funding and other resources, priority is given to general education at the expense of Deaf children. The emphasis, motivated by necessity, is on basic education for these children. More often than not children classified as disabled are often neglected [58]. Challenges exist in provision of services (mostly non-existent) to the majority of Deaf children who reside in rural areas. As a result Deaf people live in poverty and with limited access to education [58]. Deaf children grow up into adulthood with limited opportunities for higher education or jobs. When they do get employment, they are often stuck in menial jobs.

In South Africa, apartheid law segregated people along racial groups further oppressing, marginalising and disempowering Deaf people. As a result, learners attended racially segregated schools with unequal provision of resources [8, 10, 82]. The law was rescinded in early 1990s and discrimination of people with disabilities was prohibited.

In the education domain, the ‘South African Schools Act’ (No. 84 of 1996) includes a specific mention of SASL in the section devoted to language policy in public schools [88]. The Act further notes that ‘a Signed Language has the status of an official language for purposes of learning at a public school’ (Chapter 2,6(4)). This is reinforced in the Department of Education’s ‘Language in Education Policy’ (1997) which is sympathetic to the plight of the Deaf community in South Africa and to SASL. In the policy, one of the aims is to support teaching and learning of all other languages required by learners or used by communities in South Africa. These include languages for religious purposes, languages important to trade and communication and South Africa Sign Language. Furthermore it defines ‘*language*’ in the

context of the policy to mean all official languages recognised in the constitution and SASL [88]. According to South African census statistics [92], it is estimated that there are 1.5 million deaf people and the users of SASL (some of whom might not be deaf) is about 500,000 according to The Deaf Federation of South Africa (DeafSA).

Education opportunities – primary and secondary – have become available to all. However, poverty is still present amongst the Deaf community. Although SASL is not recognised as an official language, it is used in Deaf schools as a language of learning and teaching (LOLT). Opportunities for higher education, semi-skilled and skilled jobs will empower individuals and uplift the Deaf community overall.

1.2 Deaf Community of Cape Town (DCCT)

DCCT¹ is a grassroots NGO staffed almost entirely by Deaf people with hearing staff members being social workers and SASL interpreters. The NGO serves the needs of the larger Deaf Community in the Western Cape. It was founded by members of the community in response to the lack of services and support by the then national structures.

DCCT runs a number of programmes. We partner with one of the programmes called *Information Technology Computer Training Programme* (hereafter referred to as e-Learner classes to correspond to the curriculum used in the course). See Section 2.3), which provides Deaf people with access to Information Technology through the means of a certified computer literacy training programme taught by a facilitator in SASL. The training has been an ongoing activity that was originally requested by the community. Through the ICDL classes, DCCT uses computer training to uplift the community through basic computer literacy. The ICDL classes were held at the computer laboratory at DCCT and are currently open to DCCT staff members only.

The programme is also a research partnership with the Computer Science departments of the University of Cape Town (UCT) and University of Western Cape (UWC). These departments have postgraduate students working on various over-

¹<http://www.dcct.org.za>

lapping research projects with DCCT under the umbrella project: SignSupport (see Section 2.8).

The Deaf community also provided design input to the project through continuous involvement. Their insight helped us avoid the chances of a failed solution.

1.3 Computer 4 Kids

Computer 4 Kids² is a South African computer education company run by qualified educators. It was established in 1995 in order to address the critical need for information and communication Technology (ICT), digital content, training and Digital literacy support at school level.

The company administers new and existing computers centres at schools by supplying ICT education software, a relevant integrated curriculum and necessary backup and support to ensure the centres work “100% at all times”. The materials can be used in Microsoft, Apple Mac or open source environments.

The company developed the ICDL endorsed programme, e-Learner for Adults (see more details in Section 3.1.3), which is taught at DCCT. At the beginning of the research, we met with the company head who gave us permission to use the e-Learner learning material.

1.4 Community-Based Co-design (CBCD)

In this project, we use Community-based Co-design (CBCD) as our approach of which Action Research (AR) is the underlying guiding framework. In CBCD we deal with a group of people hence ‘community-based’ and ‘co-design’ conveys the notion of co-operation in a design setting where both technologists and community members are designers on an equal footing [16, 18].

The standard engineering aims to build ‘fit for purpose’ systems. This implicitly depends on users who are able to state their needs clearly to technology experts. Methods that deal with ‘clients’ are not adequate to encompass the context we work

²Computer 4 Kids - <http://www.computer4kids.co.za>

in ICT for Development (ICT4D see Section 2.2). This is because such approaches assume that the clients are similarly educated and can express their needs in a language a Computer Scientist can understand [46]. We have to work with users as co-designers and together identify the problem to be addressed, the means to address it and decide on the measures of success [19].

In one community there are smaller communities [19] for example elders, youth and women. We needed to be mindful of all these voices in the design space. In order for that to happen we needed to identify the stakeholders, gatekeepers and consider how their diverse needs would be investigated. We identified our stakeholders with whom we would collaborate in Section 1.4.1.

At the core of CBCD involves continual engagement with community members over an extended period of time. In this time, we need to remain sensitive to cultural differences and develop ways of entering design conversations with the community who are not technically skilled but knowledgeable on their own needs and how their communities operate [19].

We also have to strive for a mutually beneficial relationship [64]. The ethics of reciprocity is the best way to create something useful as a consequence of research which would be impossible if we prioritised theory over action [19]. Our co-designers (community members) have busy lives and through our approach they have committed to long term collaboration.

The community we work with in our context is DCCT (See Section 1.2) where we participate in their computer literacy training. We are entering the space as outsiders and we are cautious to keep our design decisions at bay until our co-designers have found their voice [19].

1.4.1 Multi-disciplinary collaboration

We had three stakeholders or co-designers in this project: a Deaf community, a Deaf education specialist and Computer Science researchers. We discuss them below.

Deaf community

The Deaf community play a steering role in the research. They dictate how they would use the artefact created and most of the user requirements emerge from them. Integrating their perspectives thereby increasing chances of an accepted solution. We work with DCCT (introduced in Section 1.2) on this project where we engage with their staff members who are participating in the e-Learner classes discussed in Chapter 3.

As we mentioned earlier there are communities within a community and two such communities are the Deaf learners and the other are the gatekeepers – not using gatekeeper in a negative way because they can take away our access – in our case the DCCT administrator. The administrator provide us with access to the Deaf learners who were directly involved in the project. We also had to bear in mind the Deaf learners were DCCT staff members and their duties to the community came first.

Deaf education specialist

The Deaf education specialist forms the link between the technical team and the Deaf community. The specialist is the facilitator for the ICDL classes (see Section 3.1.1). Through long term involvement with the Deaf community, the specialist provides us with the background on Deaf culture, literacy levels and helps manage the Deaf community's expectations. In addition, the specialist assists us when generating the conversation script for the recording of SASL videos.

In addition, the Deaf education specialist was also a gatekeeper. Approval of all research activities that involved the Deaf learners in the ICDL classes had to be sought through her.

Computer Science researchers

This was the technical team tasked with implementing the solution. We had to find out what mobile devices were used by the Deaf community, how they used them and for what purpose they used them.

In order to accomplish this, we had weekly visits to DCCT throughout the duration of the research. Some of the visits did not involve research at all but rather using our expertise to assist DCCT staff. The visits allowed us to immerse ourselves in Deaf culture, learn from it, build trust and relationships. We could acquire knowledge in relaxed informal interactions that would have been lost or overlooked in formal interactions with DCCT staff.

1.4.2 Action Research in CBCD

In this project, we use Action research (AR) as the guiding framework. In AR, the work unfolds in response to the situation and not to the researcher's interest [49]. The questions and problems are taken from the local context; the descriptions and theories are built by iterations within the context and tested within the situation and there is close collaboration between researchers and participants (our DCCT partners introduced in Section 1.2) [13].

AR is appropriate for our investigation, in which participants are encouraged to directly participate in the project as co-investigators. In doing so, practical results and achievements in the field solve the problem at hand [45]. It also considers the complete range of social relationships processes in which the project is doing its work.

Themes

The researcher's interests in AR are embodied in *research themes* [49] and also based on theory. Our research theme is introduced in Section 1.5. Application of the research themes to participant goals shapes the investigation. We discuss them and list the research question that result in Section 1.6.

Cycles

AR projects are iterative. They have organisations and/or communities as its subject. People make up organisations and communities. People are different in nature from data and processes and "people change over time" [12]. They cannot be undertaken in a controlled experiment where the participants react to the researcher's

treatment [94].

In this project we borrowed Susman and Evered's five step AR cycle for each iteration [94].

- **Diagnosing:** Theory, research interests, and lessons learned from previous cycle are applied to the problems faced by the community
- **Planning:** Possible solutions to the problem are discussed
- **Action:** An action is performed
- **Evaluation:** the effects of the action taken are evaluated
- **Specifying learning:** In our project we refer to it as '*Reflection*'. Findings related to the action, the community and theory are identified. These are inputs to the Diagnose step of the next cycle.

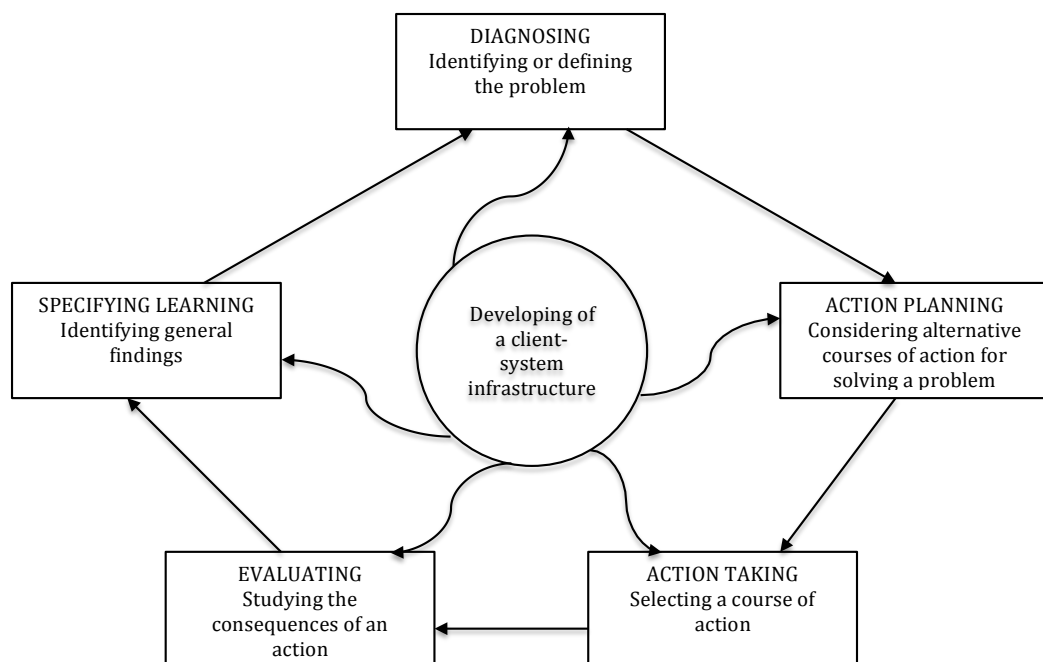


Figure 1.1: The five stages of action research process reproduced from [94]. Each cycle of our project followed the above five stages. The dissertation is organised accordingly.

This project consisted of four cycles (Chapters 4 to 7), each shaped by the aims of the NGO and our research themes. Multiple methods – Direct observations, usability

evaluation, community-based co-design, semi-structured interviews – across different cycles helped us triangulate the effects of actions.

1.5 Research Theme: Support

Our research theme is how to support computer skills training for the Deaf adults. This is explained in terms of access to e-learning materials, intermediated learning and hypermedia learning.

1.5.1 Accessibility of e-learning materials

Accessibility not only goes beyond the ease of obtaining e-learning materials but also involves the appropriate use of them. In the case of Deaf people, accessibility is impeded by a language barrier whereby learning material is available in the written form of a spoken language for example English [43, 83] taking into consideration that a large proportion of Deaf people communicate by use of a natural signed language. Spoken language contain phonemes which can be related to the written word by mind modelling [31]. Due to lack of audible components and difficulties in understanding written words, this cannot be done by Deaf people. However, it is not applicable to all Deaf people because some are become excellent readers [31].

However in our developing world context, many Deaf users lack the skills and economic power to access to these e-learning materials.

1.5.2 Intermediated supported learning

Supporting classroom learning and communication for Deaf people is more often done through an educational interpreter who is an intermediary [90]. In theory, the educational interpreter is one aspect of providing access to all teacher and peer communication, which allows the Deaf student to learn in the same manner as his or her hearing peers [90]. The Deaf people have access to classroom content but learning through an interpreter may have a difference experience given that it is mediated rather than direct [65].

Full access to a hearing classroom – in a mainstreamed setting – is complex and it involves more than the skill of the educational interpreter. Classrooms are complex environments. Accurate representation of classroom communication typically is distributed among multiple speakers and an understanding of content requires a student to integrate what many individuals say, not just the teacher [90]. This coupled with the shifts in register as well as speakers. Interpreting results in a time delay for the Deaf student which can affect turn taking [90].

Another challenge of intermediated learning is the co-ordination of visual attention to the interpreter and the visual materials [90]. Even in the best situations, Deaf learners who access curriculum via an educational interpreter will have a different educational experience than their hearing peers.

However in our developing context, many Deaf people are semi-literate at best, due to the disadvantageous education practices at schools for deaf learners [10, 19] and lack access to interpreters who are costly to hire.

1.5.3 Multimedia supported learning

ICTs have made teaching easier especially with the help of hypermedia systems and applications [14]. Successful learning has been shown in the situation where multimedia elements were introduced especially animation and video [32].

Debevc and Peljhan [32] investigated multimedia supported learning in four chosen schools in Slovenia and Estonia. They based their work on the hypothesis that web-based lectures increase comprehension of the material in comparison with traditional lectures. The web-based lectures used interpreted Slovenian sign language videos, subtitles and additional video material appropriate for Deaf people.

In their findings they concluded that Deaf students or adults using web-based on demand lectures exhibited a better knowledge of the presented material than Deaf students using traditional means. We reproduce a list of their findings [32].

- Participants learning through the traditional means depended on the teacher for the content and the teacher forgot to mention some facts although the text was similar to the subtitles in the web-based lectures.

- The participants who used the web-based lectures had a choice of reading the subtitled text or watching the video of the interpreted lesson.
- Traditional lectures had less visual material. This was because the teacher could not show the participants while he wrote difficult words on the whiteboard.
- Web based lectures had the visual material always shown at the correct time.
- Participants using the web-based lectures had the added advantage of reviewing/repeating a lecture in their own time which was not possible with traditional lectures.

A feature of multimedia based learning (in our example web-based on demand lectures) is that it is an additional aid to traditional methods [32] rather than replacing the teacher of the Deaf learners. This enables the teacher to prioritize and emphasize the portions of the lesson/lecture that are critical to the understanding of the subject. Apart from the multimedia supported learning, teachers need to have knowledge of modern computer technology and to understand the Deaf learners basic computer literacy [32]. This helps appropriate the right technology to use multimedia for learning.

1.5.4 Support for facilitator and Deaf learners at DCCT

We have mentioned in Section 1.5.2 the challenges of Deaf learners learning through an interpreter. This phenomenon has emerged at DCCT in the ICDL classes where learning is dependent on the facilitator and Deaf learners are unable to access the lesson content due to language/literacy barriers.

The facilitator's assistance was necessary for the lesson content to be accessible and useful for the Deaf learners but the regular interpreting of lesson content for the number Deaf learners would be beyond the facilitator's capacity. We discuss more in Chapter 3.

Teachers, like the facilitator, who do not have technical skills such as programming are not well positioned to create multimedia supported learning systems for

Deaf learners. In this project we designed and evaluated systems a teacher used to create content for the learners and a system for a Deaf learner to use for learning. In both systems both the teacher and the learner did not need to be aware of the technical details.

1.5.5 Application of Support theme

A multimedia supported learning system would be favourable at DCCT as opposed to the intermediated supported learning approach. This would reduce dependence on the intermediated supported learning demands on the facilitator and provide more visually stimulating learning experiences for the Deaf learner.

In the scope of the SignSupport project (see Section 2.8), we would appropriate the multimedia learning supporting system to the readily available technology considering that computer literacy and access and Internet connection would be an obstacle.

Our research interests were in whether mobile devices could be appropriated for domains other than the ones investigated in the SignSupport project (see Section 2.8) to realise DCCT's goals of community empowerment through computer literacy. This would realise our support theme which we introduced in Section 1.5.

1.6 Research questions

Our theme of *Support* we aim to reduce dependency on teachers using multimedia supported learning systems appropriated for Deaf learners. We can then determine how the systems allow Deaf learners reduce dependency on the teacher for lesson content. In the context of AR, research themes evolve as we gather more information as the research progresses. This means the research questions stated evolve as our project progresses. Our research questions arise from the research theme and DCCT's goals. They are as follows:

1. **What are the potential ways a mobile phone can reduce dependency on teachers?** The potential ways are uncovered through the field study where we engage with DCCT. We study the current approach to teaching to uncover

challenges that Deaf people encounter at the task of acquiring new skills. We measure the number of steps involved to deliver instructions, the number of times the information is represented in different forms.

- 2. How effective are mobile phones in supporting computer literacy training?** Effectiveness is a measure of the number of lesson task steps that the learners can accomplish to complete the lesson, the number of times the students interact with the teacher.

The output of this research will contribute to the understanding of the ability of technology, in our case mobile phones, support Deaf people acquiring computer literacy skills. It will also provide recoverability [49] in terms of application of mobile technology for Deaf people.

1.7 Ethics Clearance

Ethical clearance for this project was obtained from the Faculty of Science Ethics committee at University of Cape Town (UCT) (see Appendix F). We needed the ethics clearance in order to be granted permission to use Deaf people in our project.

1.8 Outline

In Chapter 2 we cover topics which are necessary to understand the rest of this dissertation. We look at the process of developing literacy amongst Deaf people in other literacy approaches. We then describe the context we operate in and introduce the curriculum we are going to use and other computer literacy projects where the curriculum has been used. We also examine the SignSupport project and the application contexts that the previous iterations of the project sought to address.

The four cycles of our action research approach are documented one per chapter. They all follow the structured approach of action research cycles. At the end of each cycle is the reflection which is a guide for the following chapter and findings of this dissertation.

In Chapter 3 we met with DCCT staff members and the facilitator. We participated in the computer literacy classes to understand the obstacles while acquiring computer skills. We also looked at the existing technology capacity in the community. The findings from this guided implementing our intervention in the following cycles.

In Cycle one (Chapter 4) we seek to address the issue of content creation. Through a Computer Science third year project we propose designs of a authoring tool to assist the facilitator (introduced in Section 3.1.1) create lessons. We supervise the project and the designs are evaluated in a usability study. The evaluation reveal usability strengths and obstacles of the different designs whereby the best features are taken further for development.

In Cycle two (Chapter 5) we examine our findings from the computer literacy classes and the mobile application to the Deaf learners which contained lesson content in sign language videos. In order to test the mobile application we conducted a usability study with the Deaf learners. The evaluation revealed some instructional inconsistencies and succeeding somewhat in allowing self learning.

In Cycle three (Chapter 6) we revisit the usability difficulties identified in Cycle one by making changes to the authoring tool. We also make changes to the lesson to make them suitable for the learners and record SASL videos of the lesson. The evaluation showed promise in that the authoring tool would allow creation of lessons despite some navigational problems.

In Cycle four (Chapter 7) we learn from the previous Cycle two by making changes to the mobile application and use the recorded lesson in Cycle three for the evaluation. We performed an evaluation with Deaf learners at different levels of computer literacy. Feedback demonstrated that the ability to self teach depended on literacy level and support.

In the conclusion we bring together the findings from the cycles and reflect on our research questions. We also look at the method, summarize the contributions in this study and discuss future work.

Chapter 2

Background and Related work

2.1 Introduction

In this chapter, we provide a discussion and critically evaluate literature relevant to our work. First we introduce the research area of Information and Communication Technology 4 Development. Secondly we look at the International Computer Driving Licence (ICDL) and the curriculum we will use. Thirdly we look at Deaf adult literacy practices and where sign language is used as a medium of instruction. We introduced sign language in Section 1.1 and mentioned that it is the first language of Deaf people. We evaluate technology and sign language video requirements (Section 2.5.2) that is geared to support Deaf peoples' communication in Section 2.5. We analyse the e-learning (Section 2.6.1) and mobile learning environments (Section 2.6.2) tailored to support Deaf learners. Lastly, we look at related work in Section 2.7 that has been done in computer literacy among Deaf people.

2.2 Information and Communication Technology for Development (ICT4D)

This project falls in the sub-discipline of ICT 4 Development, which investigates the use of technology in the developing world. ICT4D is a rather new research field in Computer Science. It focuses on the impact computing related technologies can have

on the developing world. ICT4D differs from the rest of Computer Science in terms of the context of users who are its domain of concern and also in the methods employed in artefact design. ICT4D typically targets users in under-resourced communities in developing countries [17].

ICT4D aims at digital inclusion or digital connection. This ensures that all people can access ICTs and have the skills to use them; this is often known as ‘bridging the digital divide’. Tucker [97] defines ‘digital’ divide as the growing gap that exists between those who have access to resources of the global information revolution and those who are deprived of such due to gaps in their education, personal handicap, poor digital infrastructure, or lack of advanced computer equipment. Digital divide is not merely a question of access but also about being able to use appropriate resources. Other digital divide disparities include race, gender, disability, location and income level.

The preconceived solutions for solving poverty problems in developing countries led to the setup of telecentres that had been rolled out in Europe and North America. Unfortunately, these efforts resulted in failure [15,46,47]. The need for more specific ICT4D research and training, driven by the high failure rate of ICT projects [46] in the developing world has led researchers to abandon traditional methods of design in Computer Science [17].

2.2.1 Difficulties of Design in ICT4D

ICT4D projects risk not addressing users’ real goals even after successfully deployment. User Centred Design methods (UCD) put emphasis on user goals. However, UCD techniques are difficult to adopt in developing contexts. Many of the issues that plague adoption of technology for a different context also affects the relationship between users and designers from different contexts.

Some difficulties exist in terms of physical access due to geographical location [42] or security [27]. In the case of the same geographical locality, language and cultural barriers or misunderstandings may occur [42]. Even with the presence of researchers and communication being established, users with no computing familiarity may have difficulty in providing feedback [27]. They also may be reluctant to express criticism

of the work of researchers due to what they perceive as appropriate criticism or viewed as impolite [27].

As a solution to these difficulties, one approach is working with “human access points” [66] and also cited by [98]. These are people who understand the community but also have sufficient knowledge of technology and are able to provide useful feedback to researchers. However we work with a community, DCCT composed of individuals with complex needs (see Section 1.2). Our approach is Community Based Co-Design (CBCD) introduced in Section 1.4 because of the lengthy engagement of working with the community and the multidisciplinary work involved in the project.

2.3 International Computer Driving Licence

The International Computer Driving Licence (ICDL) (known as European Computer Driving Licence – ECDL – in Europe) is an internationally recognized Information Technology literacy skill certification programme. Its objective is to raise the level of core knowledge about Information Technology (IT) and computer skills competency on a global basis and provide an internationally recognized certification [3, 25]. We shall refer to it as ICDL.

The ECDL foundation has three main programmes, ICDL, Equalskills¹ and e-citizen that form the main core. There are 13 other IT certification programmes that ECDL endorses which are designed and created by other organisations for specific target groups [39]. ICDL enables an individual to develop and certify their computer skills of their choosing and up to a level they need. EqualSkills is an introduction to computers and the internet to people with no previous experience. E-citizen explains how to use the Internet effectively to communicate with people or groups of people, retrieve information and access products and services [39]. It is offered to people who feel they lack the necessary Internet skills.

In our work, we use the ECDL endorsed programme, e-Learner² [3], developed by the educational company, Computer 4 Kids (see Section 1.3). This programme

¹Equalskills - <http://www.ecdl.org/programmes/index.jsp?p=2227&n=115>

²e-Learner – <http://www.e-learner.mobi>

is offered to schools and adults at Computer 4 Kids training centres. The e-Learner Adult covers the seven units as part of the e-Learner certification programme [1]. It is aimed at users who do not need or require high-levelled international certification but who want some form of certification covering the basic Office suite. If a candidate needs a higher level international certification, the candidate may proceed to the ICDL programme. The seven units of the e-Learner are as follows:

1. Basic concepts of information technology
2. Using the computer and managing files
3. Word processing
4. Spreadsheets
5. Databases
6. Presentations
7. Information and communication

ICDL was introduced in Finland then promoted at a European level [25] by Council of European Professional Informatics Societies (CEPIS)³. Currently, the governing body of the programme is the European Computer Driving Licence Foundation (ECDL-F)⁴. ICDL South Africa [53], the local chapter of ECDL-F, is the certification authority that manages the programme in our country. The ICDL programme can be summarized as follows:

- *Internationality*: 148 countries worldwide have adopted the programme. The certification exam is based on the so-called QTB (Question and Test Base) [24] available in 41 languages.
- *Integration between academia and industry*: The programme is supported by national professional societies that integrate professional and academic competencies.

³CEPIS - <http://www.cepis.org>

⁴ECDL-F - <http://www.ecdl.com/>

- *Technological neutrality*: It defines ICT skills independently of hardware and software vendors. This makes it possible to obtain the certificate using only open source technologies.

The ICDL certificate proves that its recipient possesses the some basic skills in using a computer, such as editing a document with a word processor, preparing a table using a spreadsheet, browsing the Web. The ICDL curriculum is composed of modules in three categories [53]:

- **Base modules**: Computer essentials, online essentials, word processing and spreadsheets.
- **Standard modules**: Presentations, using databases, online collaboration, IT security, project planning, web editing, image editing and 2D Cad.
- **Advanced modules**: Advanced word processing, advanced spreadsheets, advanced database and advanced presentation.

The certification is released to whomever correctly performs a set of activities randomly extracted from the QTB, not available to the public [24]. The exam is fully automatic. There are two types of certificates: a START licence (obtained after passing four out of seven ICDL modules) and a FULL licence (obtained after passing all seven ICDL modules). Exams take place in test centres. In South Africa, these centres are specifically accredited for this purpose by ICDL South Africa.

ICDL targets the general population who want to use a personal computer competently. The qualification formally shows that workers, students or citizens, with their certificates, exhibit the basic knowledge and competence in personal computer use [87]. The certification is also important to employers to assess an employee or potential employee's skill [87]. Employees with ICDL certification are more favourable than those without in today's computing world.

2.4 Deaf Adult Literacy

Internationally, the average reading age of Deaf adults is said to be at fourth grade level [30,86,100]. In the context of South Africa, the situation is complex. The aver-

age reading age of Deaf adults who have attended schools for the Deaf is lower than the international fourth grade average [8, 10]. In addition, apartheid caused racial inequities of educational development and provision resulting in varying literacy levels in Deaf people across different racial groups [82].

2.4.1 Deaf literacy practices

Low literacy levels among the Deaf can be attributed to educational practices of the past. Following the World Congress of Educators of the Deaf held in 1880 in Milan, schools followed a policy of Oralism [60]. This meant that the Deaf learners received their schooling through the medium of a spoken language. This meant learning lip-reading and being made to speak. The implications of Oralism meant that the Deaf learner spent more time developing lip-reading and speech skills at the expense of general education development, including reading and writing skills [60]. Resolutions passed in Milan were later reversed by the same congress in Vancouver 2010 [37].

In 1970s, a philosophy of Total Communication was introduced into many Deaf schools worldwide and in South Africa [34], where a combination of speech and manual signs were used. However, in practice, Total Communication was basically speech with some sign support [56]. Schools for the Deaf adopted a policy of using a manually coded language, which was a system that tried to represent English (or any other spoken language) manually. This system made use of lexemes⁵ (Lexeme is basic lexical unit of a language consisting of one word or several words, the elements of which do not separately convey the meaning of the whole) of one language (signed language) with inflections and word order of another (a spoken language). This failed because the Deaf learners were exposed to neither a full version of English nor to a full version of the signed language because each language had its own grammatical structure [43]. Therefore, it was not possible to produce both languages in their full form at the same time and learners ended up learning neither the signed language nor the written language.

⁵Lexeme - <http://www.oxforddictionaries.com/definition/english/lexeme?q=lexeme>

Grosjean [44] suggests it was better for people to learn through the medium of their first language, rather than through a second language. All over the world, educators have begun using the natural signed language of the Deaf community as a medium of instruction in schools for the Deaf and teach a written language as the second language [85]. In South Africa, despite policy advocating the use of South African Sign Language (SASL), there is still resistance to this approach. This is partly fuelled due to the fact that there are few teachers of the Deaf who are fluent in SASL. Many educators of the Deaf are mistaken that the signed language is based on the local spoken languages [8]. This leads to the incorrect assumption that there are 11 different signed languages based on the 11 official languages in South Africa. Despite the different vocabulary variations, there is only one basic signed language in use in South Africa. It is an independent language with its own grammar, and linguistically complex as any other language [43]. There are Deaf people who can read and write, proving that learning is not necessarily based on phonological awareness (a knowledge of sounds) [43].

A ‘Bilingual-Bicultural’ approach [44] is an approach where Deaf learners are taught through a medium of signed language to read and write the written form of a spoken language. Various projects have been conducted in which Deaf children have been taught using this approach [85]. The two languages used are the signed language and the written form of a spoken language. As Deaf learners develop literacy in the written form, they become increasingly able to access written material [43]. Research has shown that Deaf learners who use and are taught in sign language perform better than learners who are not taught this way [85].

2.4.2 Deaf adult literacy in South Africa

There is little information on the development of literacy in adult Deaf populations, both internationally and in South Africa [43]. Additionally there is not much research about the structure of South African Sign Language (SASL) [43]. SASL has not been officially recognized as an official language though it is used among Deaf people in South Africa as their first language. Despite policy changes which advocate for the use of SASL as a language of learning and teaching, there is still

resistance to this approach. This is fuelled by the fact that there are few teachers of the Deaf people in South Africa who are fluent in SASL [43].

Glaser and Lorenzo [43] present an approach that aims to redress the low literacy levels among Deaf adults in South Africa. Their approach uses the learners' existing knowledge of SASL and written English, highlights the differences between these languages and facilitates the development of their second-language skills in written English. SASL is a face-to-face language and written English is not. There are obvious differences that the learners need to recognize. Spoken and sign languages are primary communication forms, the written language is a secondary communication form [43]. In the case of the Deaf learners, literacy is moving from a primary to a secondary communication form as well as moving from one language to another. Learning to read and write, therefore, is a matter of becoming bilingual, as well as literate.

Due to the difference in grammatical structure between SASL and English, it is impossible for a direct translation of SASL sign-for-word into English or translating English word-for-sign into SASL. Thus, signed language is not a direct translation of a spoken language [43].

2.5 Deaf Communication Technologies

In this section we review technologies that are geared to supporting Deaf people communicate with each other or with hearing people. The insights obtained here have consequences for our work that we review in this chapter.

2.5.1 Video Requirements for Mobile Sign Language Communication

A mobile video compression project at the University of Washington called MobileASL uses American Sign Language (ASL) as its medium of communication on a mobile device in real-time. The project was developed to enable Deaf people who use low to mid-range commercially available mobile devices to send sign language video over a mobile network. Its aim is to make video communication possible on

a mobile device without the need for specialized equipment like a high-end video camera [26], but instead to use the standard equipment on the mobile device.

MobileASL project concentrated on three video properties as described below:

- **Bit rates:** Three different bit rates were chosen for the study: 15, 20 and 25 kilobits per second (kbps). These bit rates attempted to accurately portray the current United States (US) mobile phone network. Results revealed that there was a statistically higher preference for the higher bit rate 25kbps over 20kbps. The US mobile networks have an optimal download rate of 30kbps and an upload rate of 15kbps. The 25kbps bit rate was chosen regardless of the frame-rate and region-of-interest values discussed in the following points [26]. We chose not to consider bit rates because we had no use for data transfer.
- **Frame rates:** Two different frame rates were tested: 10 and 15 frames per second (fps). Initial tests with a certified sign language interpreter revealed no significant difference between sign language videos recorded at 10fps compared with 15fps. The difference between 15fps and 30fps was negligible whereas at 5fps signs became difficult to watch thus establishing low frame-rate videos unusable for ASL [26]. The two frame rates were chosen as a tradeoff for fewer frames (10 fps) at a slightly better quality or more frames (15 fps) at slightly worse quality for any given bit rate.
- **Region of interest:** The region-of-interest are the face, hands and upper body movement of the signer. Three different of region-of-interest (ROI) values were tested: -0 (standard encoding), -6 (two times better quality in the face region), -12 (four times better quality in the face region), where the negative value represents the reduced quantizer step size out of 52 possible step sizes. Concentrating on these regions, MobileASL enhances the quality of the sign language video on these regions (region-of-interest) and reduces the quality of the video on regions that are not of interest like the background. The resulting video is smaller, can be transmitted over a cellular network and is considerably more intelligible for sign language [29].

Results from MobileASL project indicate that reducing the frame rate to 10 frames per second (fps) and increasing the quality of the image near the signer's face may help yield more intelligible ASL for low bit rates [26]. These video compression techniques make it possible to transmit intelligible sign language videos over a mobile network. In addition, Deaf people expressed an interest in using MobileASL in their daily lives for communicating with other Deaf people.

MobileASL's goal was to reduce the size of intelligible sign language video for transmission over mobile network. The 10 fps reduced the number of frames to encode and the -6 ROI encoding around the face made the video small enough to transmit but also intelligible for the participants to recognise. However, in our work we do not intend to reduce frame but rather increase it for a better quality sign language video. MobileASL's authors mentioned that between 10 fps and 15 fps there was no significant difference. We choose a frame rate higher than 15 fps for our work. We shall determine the exact figure when we examine the video encoding parameters in Section 2.5.3.

2.5.2 Sign Language video requirements communication

The minimum quality requirements for successful use of video via a visual language, such as sign language, are documented in the *ITU-T Series H Supplement I (05/99)* document released by ITU [54]. The requirements apply to signed languages and lip-reading video material for telecommunications.

The ITU is the United Nations Specialized Agency in the field of telecommunications. The ITU-T is the permanent organ of ITU that is responsible for studying technical, operating and tariff questions issuing recommendations on them with a view to standardise telecommunications on a worldwide basis.

ITU-T Series H Supplement 1 describes the factors taken into account for visual language communication. The document sets the minimal requirements to ensure successful person-to-person communication using a video system. Video compression is ignored in the requirements and the focus is on resolution and frame rate. The requirements are not to be considered as an absolute and may change depending on the situation.

ITU-T proposed that 20 frames per second provide good usability for both sign and lip-reading, while still understandable at 12 frames per second. Between 8 and 12 frames per second usability becomes very limited, with no practical usefulness below 8 frames per second.

In terms of resolution, Supplement 1 concludes that it is possible to use Quarter Common Intermediate Format (QCIF) (176x144 pixels) resolution, with an increase to Common Intermediate Format (CIF) (352x288 pixels) giving a better language perception. Sub Quarter Common Intermediate Format (SQCIF) (112x96 pixels) is too coarse for reliable perception with some signs occasionally perceivable.

2.5.3 Supported Video formats on Mobile Devices

The three common mobile operating systems Apple iOS, Android and Windows Phone have different video requirements which will be discussed below. All operating systems support video capture and playback, but for our work we shall only be concerned with video playback.

Android

Android media framework supports video encoding and playback in the H.264 Baseline Profile codec and the VP8 codec [6]. Table 2.1 below lists the examples of video encoding parameters which were available since Application Programming Interface (API) level 8.

Table 2.1: Examples of video encoding parameters for the H.264 Baseline profile sourced from [6]. * HD 720p is not supported on all devices

	SD (Low quality)	SD (High quality)	HD 720p*
Video resolution	176 x 144 px	480 x 360 px	1280 x 720 px
Video frame rate	12 fps	30 fps	30 fps
Video bitrate	56 Kbps	500 Kbps	2 Mbps
Audio codec	AAC-LC	AAC-LC	AAC-LC
Audio channels	1 (mono)	2 (stereo)	2 (stereo)
Audio bitrate	24 Kbps	128 Kbps	192 Kbps

Table 2.2: Examples of video encoding parameters for the H.264 Baseline profile sourced from [6]. *HD 720p and HD 1080p is not supported on all devices

	SD (Low quality)	SD (High quality)	HD 720p*	HD 1080p*
Video resolution	176 x 144 px	480 x 360 px	1280 x 720 px	1920 x 1080 px
Video frame rate	12 fps	30 fps	30 fps	30 fps
Video bitrate	800 Kbps	2 Mbps	4 Mbps	10 Mbps

From the Table 2.1 and Table 2.2 we see that the minimum supported encoding frame rates (12 fps) are higher than the ideal 10 fps frame rate identified in Section 2.5.1

The H.264 supports the 3GPP (*.3gp*) and MPEG-4 (*.mp4*) video file formats while the VP8 code support (*.webm*) and Matroska (*mkv*) file formats.

Windows Phone

Windows Phone supports the video codecs (H.263, VC1 and MPEG-4 Pt 2) but the H.264 video codec works on all Windows Phone devices. For the purpose of our work, we shall focus on the H.264 codec. The 3 tables (Table 2.3) below lists the encoding parameters for H.264 codec. The encoding parameters are determined by the processor in the Windows Phone.

Table 2.3: Examples of video encoding parameters for the H.264 supported by the Qualcomm Snapdragon S4 (MSM8x30, MSM8960) and Snapdragon 800 processors sourced from [5]

Feature	H.264	H.264	H.264
Profile	Baseline	Main	High
Max average bit rate	20 Mbps	20 Mbps	20 Mbps
Max resolution and frame rate	1920 x 1080 @ 30 fps	1920 x 1080 @ 30 fps	1920 x 1080 @ 30 fps
Video file formats	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov

In Table 2.4 the following H.264 codecs are supported on the Qualcomm Snapdragon S4 (MSM8x27) processor.

Table 2.4: Examples of video encoding parameters for the H.264 supported by the Qualcomm Snapdragon S4 (MSM8x27)

Feature	H.264	H.264	H.264
Profile	Baseline	Main	High
Max average bit rate	14 Mbps	14 Mbps	14 Mbps
Max resolution and frame rate	1280 x 720 @ 30 fps	1280 x 720 @ 30 fps	1280 x 720 @ 30 fps
Video file formats	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov

Table 2.5: Examples of video encoding parameters for the H.264 supported by the Qualcomm Snapdragon S1 (MSM8x50) and Snapdragon S2 (MSM8x55)

Feature	H.264	H.264	H.264
Profile	Baseline	Main	High
Max average bit rate	10 Mbps	10 Mbps	10 Mbps
Max resolution and frame rate	1280 x 720 @ 30 fps	1280 x 720 @ 30 fps	1280 x 720 @ 30 fps
Video file formats	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov	3gp, 3g2, mp4, m4v, mov

Table 2.3, Table 2.4 and Table 2.5 above we see that all the processors mentioned above support high frame rates of 30 fps. In addition the video resolutions are high ranging from the highest of 1920 x 1080 pixels and 1280 x 720 pixels. There are other Windows phone devices with the Qualcomm Snapdragon 8x50 processor that support resolutions at 720x480 @ 30fps or 720x576 @ 30 fps. This processor supports a lower resolution compared with the other processors [5].

As much as the maximum video resolutions and frame rates are high on Windows phones, the variability in processor types make it difficult to ensure consistency amongst all the devices.

iOS

Apple's iOS operating system supports video playback through the Media player framework [35]. The framework provides high-level support for playing audio and video content from your application. The framework supports the following video codecs shown in Table 2.6

Table 2.6: iOS supported video formats parameters for the H.264 and MPEG-4 sourced from [35]

Feature	H.264	H.264	MPEG-4
Profile	Baseline	Baseline up to level 1.3	Simple
Max average bit rate	1.5 Mbps	768 Kbps	2.5 Mbps
Max resolution and frame rate	640 x 480 pixels @ 30 fps	320 x 240 pixels @ 30 fps	640 x 480 pixels @ 30 fps
Video file formats	.m4v .mp4 .mov	.m4v .mp4 .mov	.m4v .mp4 .mov
Audio codec	AAC-LC	AAC-LC	AAC-LC
Audio bitrate	160 Kbps	160 Kbps	160 Kbps

From Table 2.6 we see that the iOS supports videos playback at 30 fps. Other functionality supported by the framework are as detailed in [35].

- Playing video to user's screen
- Configure and manage movie playback
- Display Now Playing information in the lock screen

2.5.4 MotionSavvy

MotionSavvy is a project in the United States that developed the UNI. The UNI is a device that translates American Sign Language (ASL) into audio and speech to text [69]. The UNI uses advanced gesture recognition technology called the Leap Motion [68] that allows users to see how their signs appear on camera which helps to make sure signs are inputted correctly and to avoid missing important information [69].

MotionSavvy is a rather new project and uses advanced gesture recognition devices that are costly to acquire and out of the reach of the Deaf community especially

in South Africa. Secondly, the UNI is only trained to recognise ASL signs.

2.5.5 Way Forward

Based on the results from MobileASL, the video frame rates and bitrate form much of the background of our work with intelligible signed video on mobile devices. However, unlike MobileASL our work eliminated data costs by storing the videos on the device's internal memory. Therefore, we chose to have a larger storage space instead of a stable fast internet connection. We chose our frame rate to be 25 *fps* as a middle ground.

The region of interest (ROI) was not considered for our focus of study. Despite its use for reducing the video size, we did not find additional need for compression.

However, the results since MobileASL, video encoding has advanced supporting higher frame rates and resolutions on mobile devices particularly smart phones. In section 2.5.3 we have discussed the supported video encoding formats supported on the major mobile operating systems. We see that the minimum frame rate of 12 *fps* in Android and a maximum of 30 *fps*, which is consistent with Windows Phone and iOS mobile operating systems. We choose a frame rate of 25 *fps* as a middle ground. It is significantly higher than the results from MobileASL and lower than the 30 *fps* supported on the various mobile operating systems.

2.6 Digital Learning Environments

In this section we discuss the different digital learning environments focusing on e-learning and mobile learning environments that support accessibility to people with disabilities concentrating on Deaf people.

2.6.1 E-learning environments

We discuss a number of projects that develop e-learning environments geared for Deaf students. We critically evaluate their approaches to solve Deaf learners needs.

TERENCE Project

TERENCE (An adaptive learning system for reasoning about stories with poor comprehenders and their educators) was a project dedicated to design and develop the first Adaptive Learning System (ALS) for poor comprehenders, hearing and Deaf, and for their educators [95]. The system aimed to help educators in their daily work with 7-11 year old children with profound text comprehension problems.

TERENCE employed stories as reading material, and tackling specific high-level cognitive text processing skills through adequate smart games for reasoning about stories. Smart games, written in both English and Italian, are developed and classified according to specific pedagogical models to stimulate children to reason about the events of the stories.

An interdisciplinary team (art and design, computer engineering, linguistics and medicine) developed the guidelines, models and the entire learning system. The project team continuously involved the end-users both children with hearing difficulties and their educators from schools in Brighton (United Kingdom) and Veneto region (Italy) [95]. The system allowed the teachers to choose and tailor the types of stories and games according to the needs of their learners.

In TERENCE, the simulation of a learner takes place in a virtual environment. The learner chooses a story that takes place along a spatial map with a certain scenario, and a companion avatar. Each story was divided into chapters and each chapter was visualised in a specific location in the map with its own games. Learner progress from one chapter to the next depended on his/her resolution of the chapter's games. The difficulty level of the games is dependent upon the adaptation engine and possibly by the educator [67].

We note a few differences and similarities with our work. We collaborate with an interdisciplinary team comprised of a Deaf education specialist and Deaf users. The Deaf education specialist provided context to our work. The Deaf users, who are 'experts' in the own communication context. Our system targets adults with minimal access to computers. We have spoken about how limited resources in Deaf schools resulted in unequal access to education in Section 1.1.

DEAL-TOI

DEAL project (*Deaf people in Europe Acquiring Languages through E-Learning*) was a project co-financed by the European Commission. The project created an e-learning model and course for teaching foreign languages to Deaf individuals in professional education. The languages taught were Italian Spanish and German and the project ran from October 2006 to September 2008. The subsequent project Transfer of Innovation (DEAL TOI) [76] partnered with authoritative institutions in Austria, Italy, Spain and the United Kingdom in the field of deafness and education. Their objective was to create an e-learning model for teaching foreign languages to Deaf individuals in professional education.

Deaf people all over Europe regularly attended vocational and re-qualification training. In addition, performing secretary tasks in a firm context was one of the most popular employment change open to Deaf people. However, based on the experiences and research carried out, the training delivered to Deaf people was not effective enough in some employment areas and foreign language skills were not developed enough [76]. These were important to enter the labour market and to carry out the secretarial tasks to which Deaf people are oriented. The project was extended to include English as a response to feedback from educational bodies and national associations of Deaf people. English language was now an essential element in vocational training for Young Deaf people in European countries studying to work in business [76].

An e-learning platform was chosen as the best strategy. The e-learning platform was the most appropriate tool for teaching/learning because it operated through the visual channel, the main channel used by Deaf learners. Furthermore, the platform could connect Deaf students with each other allowing for mixed conversation, signing or writing [76]. The platform could also monitor users' actions, not only to assess students, but also activate real-time tutoring strategies.

The interface was redesigned to meet the needs of the target group, taking into account the Deaf peoples' learning styles. The system also incorporated a full integration of national Sign Language videos with learning objects also being developed. Integration of a video conferencing system that was platform independent was cru-

cial to making their software work. It worked on users' operating systems (Windows, Linux, OSX), not requiring specialist plugins or special hardware but used simple additional tools that allowed for recording of all interactions. The platform chosen was based on open meetings (<http://code.google.com/p/openmeetings>)

In the e-learning model, tools/content available to the learners are in the form of animated scenes with subtitles, videoconference, video explanations in sign languages (BSL, LSC, LIS) and interactive teaching activities.

We note some similarities with our work. The project supported learning of new languages which was beneficial to Deaf people allowing them to seek more employment opportunities. Our work sought to support computer skills training for Deaf learners to open more opportunities to higher education or employment for them. We have discussed how DCCT used computer literacy as a community upliftment tool in Section 1.2.

Our approach would incorporate sign language videos to access learning material similar to DEAL-TOI. The authors see the integration of the sign language videos into the e-learning environment being appropriate to the Deaf users because of their visual nature. This suggested that we introduce sign language videos into our system. In addition, the authors avoided using specialist software or plugins to make the system widely available on multiple platforms. This suggested use the of commercially available software that would provide a wider reach of the system.

In addition, DEAL-TOI was distributed free of charge [76]. The course material used could be adapted for Deaf students of other nationalities by the creation of videos in their national sign languages. We intended to have our system 'plug and play' meaning the content could be adapted to other signed languages once videos of the lesson material was recorded.

DELFE

DELFE – (*Distance and Life Long Training for the Deaf People in the E-Commerce and New Technologies Sector via e-Learning Tools*) [36] was a European Union Leonardo project. The project carried out in Greece aimed at developing an e-learning environment for Deaf people adapted for them via sign language. The

environment utilised advanced teleconference services of Internet to offer a sum of facilities to enable support via an easy friendly way.

In addition, the project designed and developed *adaptive* material for Deaf users in the form of web included. The informative material was based on the animation, and streaming video (multimedia) directed towards the aim of training in e-commerce and new technologies of the Internet. The material was all translated into sign language via the streaming digital video [36].

The creation of a web portal and a human network of educators, technicians and educators within the specific domain of Deaf people. The portal and network facilitated information circulation to and from professionals and Deaf students. Moreover, it will provide feedback and demands from the Deaf community (students and professionals) to industry.

DELFE incorporates web technology and teleconferencing to disseminate learning material over the Internet making distance learning viable. E-learning materials were made accessible by translating it into sign language, similar to what we intend to do in our project. We differ with DELFE in our approach to disseminating by not using the Internet but rather flash animations, web portal and extending to an mobile learning environment.

DELFE's human network with its interdisciplinary expertise provided the necessary support to make the project sustainable. The expertise in the different domains provided feedback to support distance learning using the e-learning tools. We saw the benefit of doing interdisciplinary work.

Work in this project demonstrates the sustainability of the DELFE system. The authors show that the support system put in place in terms of domain expertise. We see the benefit of employing this methodology in our work in order to ensure sustainability of our system. We have mentioned in Section 2.2 the problems of designing systems with users from different contexts. In our approach we attempt to understand the context which we introduce in Chapter 3.

Deaf-centred e-Learning Environment (DELE)

DELE is a learning environment that is geared towards Deaf adults attending university. The founding principle of DELE is to avoid text wherever possible and rather opt for a visual representation of the learning activity [20].

Signed languages (SLs) are used as the main accessibility tool in projects above DELFE and DEAL-TOI however, in this study there was a group of non-signing Deaf users. The authors also question the “foundations” of the frameworks adopted. These frameworks had information fully textual or had a table structure in which each element (links, maps, videos etc) were encoded primarily in the written language. This formed the first boundary in-front of Deaf users which hindered real accessibility of e-Learning environments [21].

In their approach, the authors investigated a coding model to represent information through channels that were primarily non-textual, while guaranteeing the integrity of the content. Use of text was restricted whenever it did not have an educational role, instead iconic presentation of information was adopted.

The Design of DELE was based on the work of Johnson in Embodied Cognition theory [55] which the authors cited. They used *Conceptual metaphors* as a fundamental way to convey information and the authors cited work of Bruner, McDrury and Alterio on the theory of *Storytelling*. The design investigated how metaphors based on the concrete experiences made by humans interacting with their environment, can facilitate learning. The metaphor, “learning path as a story” fit their application context. The learning paths were viewed as stories with a starting place, steps and a conclusion. This view allowed for information to be organised visually effectively, which met the difficulties that Deaf students encountered. Furthermore, the metaphor was particularly stimulating for the target group.

The ‘learning story’ brought up a result: the design of an ad-hoc editor [22] called *StoryEditor*. This editor allowed tutors to design learning paths as stories. The editor was a web-based graphical editor integrated into DELE. Learning story paths were composed of several conceptual nodes. Teaching materials (text, video etc) were inserted by creating nodes into the editor and connecting them through simple graphical wires [22].

We can relate the work in DELE to our proposed approach. Firstly is the *Storyeditor* which allowed the tutor to design stories for the Deaf students without the need for a programmer. The tutor can be a domain specialist with different expertise but still with relevance to Deaf education. In our research we work with a domain specialist.

Secondly, DELE use SLs as a tool for accessibility though not entirely. We discussed DCCT's use of SASL as their primary language in Section 1.2. We propose use of sign language (SASL) primarily as an accessibility tool and instruction language but also developing their secondary written language, viz. English.

DELE's online learning environment was designed for Deaf students with access to computers. However in our work, our target user group the majority do not have regular exposure to computers. The users come from a resource constraint socio-economic background (see Section 1.2). Consequently access to online content would not be viable and too costly.

2.6.2 Mobile Learning (M-learning) environments

We discuss the different mobile learning environments that support learning activities for Deaf people.

Accessible Mobile Learning Environment (AMobiLe)

A project carried out by the Italian National Research Council, Institute for Education Technologies developed an online environment called AMobiLe for mobile learning with specific features for disabled students. AMobiLe was developed to support disabled students in their learning activities during on-site experiences [11]. It incorporated a multimodal interface system which combined a well designed GUI with a 'Live' Text To Speech (TTS) to improve learning experience, offer opportunities and overcome some of the learning barriers. To support all learners, AMobiLe system produced information redundancy so that every graphical and audio element had a corresponding textual description. Where an alternative description was not available, the multimedia was removed.

The environment was focussed on student mobility and on contextualised information. The learning environment was also accessible via desktop computers in class or at home through a smartphone with GPS during on-site learning activities. Teachers designed the learning activities and they defined the points of interest (POIs) correlated to that learning activity. Thus, during their visiting experience, students have to answer the questions prepared by their teachers [11].

The testing phase of the system was based on the assumption that the subjects involved did not only use the system but played an active role in the creation of the framework [11]. The pre-testing results with two visually impaired and sighted participants revealed several bugs and changes were made to improve usability. The authors planned for an extended testing phase in a more formal learning context, designed to allow both visually impaired and sighted students to have an on-site experience with a mobile device. The authors designed a system with the intention of providing accessibility to people with disabilities. Built into their system was information redundancy and a multimodal interface with a Text-to-Speech interface with an inclination to visually impaired people.

In addition we see from AMobiLe the use of smartphones for learning. We see from this project the benefit of capitalising on the ubiquitous nature of mobile devices. We see the use of GPS (Global Positioning System) capabilities of the smartphone to learn in a contextualised situation. In addition learners could record hypermedia notes while on site [11].

Similar to AMobiLe, our proposed system allows teachers to design/author lesson content. In addition, our approach focused on student mobility to allow them to learn on a mobile device in the classroom or at home. We differ with AMobiLe in terms of offering an online environment but our system has a content authoring tool which is on a desktop computer to allow a teacher to create lesson material. The online environment is a difficulty due to cost of data access in South Africa [23] and the socio-economic background of Deaf people who have little economic power to purchase desktop computers for personal use.

2.6.3 Way Forward

In the e-learning environments (DEAL-TOI, DELFE and DELE) above, use of sign language as the main accessibility tool with the exception of TERENCE project where interactive educational video games are used for children. Visual representation of textual information was used in representing learning content. We adopt a visual representation of lesson content in our project. We use SASL as the main accessibility tool for the learning content and the written form of English in some cases using the *bilingual-bicultural* approach (see Section 2.4.1)

The above learning environments are all online and computer based. They all assume Deaf users have a level of basic computer literacy. Our target users (see Section 1.2) have limited economic power and limited or no prior exposure to computer literacy. Access to computers is a challenge for our target users. Mobile devices are the first computer-like devices our target users are exposed to. We also note that internet access is costly due to our target users poor socio-economic background.

AMobiLe capitalised on the ubiquitous nature of mobile devices to provide distance learning. The designed interface provided accessibility features for people with disabilities in general with an inclination towards visually impaired people.

Similarities emerge from DELE and AMobiLe in terms of content authoring. Both projects have tutors and teachers respectively designing/authoring learning material. Content authoring by domain specialists such as teachers allowed for independence and flexibility to design learning content as they desire and suitable to the learners needs. We identify the benefit of having domain specialists author content for Deaf learners to avoid reliance on programmers or third parties.

2.7 Computer literacy projects

There are a number of projects that have sought to address the increasing education level of Deaf and hard-of-hearing persons. To truly meet the needs of users, in addition to providing guidelines based on technology, it is necessary to understand the users and how they work with their tools [96]. Below are some projects aimed to increase computer literacy levels among Deaf learners.

2.7.1 Project DISNET

Work in this project adapted an e-learning environment, presented for people with special needs especially Deaf and hard-of-hearing persons. The project carried out in Slovenia in 2006 had 337 people participating of whom 22 were Deaf and hard-of-hearing. It incorporated ICT and multimedia materials in a web-based virtual environment making it powerful for this special group of users. The aim of the project was to increase computer literacy among the Deaf and hard-of-hearing learners by using the ECDL/ICDL e-learning materials [33]. The authors focused on the following points:

- Explanation and design of e-learning material and working principle of the system. For an illustration, a short course for e-learning to complete the ECDL modules will be presented.
- Consideration of the needs and demands of the persons with special needs (focus on Deaf and hard-of-hearing persons) and hereby enabled them accessibility to e-learning material.
- Description of adapted Learning Management System (LMS) Moodle and working principle using an adapted version of ECDL materials.

The sections below discusses the focus points of the authors.

ECDL modules and need analysis

The e-learning materials used in project DISNET for the education of unemployed adults was the curriculum that had been defined by the ECDL Foundation [25]. The education process took place in the form of courses following a method of blended learning [80]. In the beginning, students met with their tutors and had their first training in a computer room. Further training consisted of individual work through web-based learning material at their homes or at special public ICT-equipped centres. Schedules were set up defining the time frame when tutors were available through the system for additional help. Moodle [38], a course management system

(CMS), provided the support for distance learning because of its user-friendliness, since it supports setup on different platforms.

The needs analysis of Deaf and hard-of-hearing users was made in order to define the design guidelines. This needs analysis was stated in order to increase the availability of learning software for Deaf and hard-of-hearing persons. The ten design guidelines were as follows:

1. To present all audio information visually.
2. To assure the translation of spoken and written text in to sign language using quality video picture.
3. To present subtitles in the video.
4. To offer at least two difficulty levels of text and graphic presentations.
5. To offer a dictionary and a glossary of terms.
6. To assure additional hyperlinks for gathering detailed information.
7. To present a quick and understandable navigation inside the learning material.
8. To assure that web based e-learning material is structured in understandable and logical way.
9. To present a simple user interface in a learning management system offering the tools for user interface personification.
10. To assure that the written language and explanations are relatively easy and readable.

In terms of the video material, the authors considered the main criteria improved video quality. The benchmark of the criteria was established by measuring the quality of video communication between Deaf persons as well as according to standardization of video pictures for Deaf persons discussed in Section 2.5.2. The video quality enabled them to capture all the details related to the movements of hands, eyes and mouth clear enough for recognition by a Deaf person. The subtitles follow a strict guideline. All text equivalents for spoken text, as well as sound

information (for example signals of the operation system.) must be presented. This information was found useful during the needs analysis while following the spoken text and background sound [33].

Description of an e-learning system

Moodle was used for e-contents management and for supervising the activities and progress of the participants. The tools and functions Moodle represent the base support for e-learning, for example: multimedia support contents, forums, questionnaires, chat email, etc. In the study, almost all offered tools were used to offer an alternative form of communication.

The e-contents were presented in a simple web (HTML) page. The design was kept simple to avoid complex graphic elements in order to reduce influence of disturbing factors that could divert attention from the content [33].

The contents within individual topics were divided into two levels: basic and advanced. Basic levels designed for users having only basic computer skills or beginners. Advanced level was designated to users experienced in basic work with the computer. At the end of each lesson, short questions were given that the user could answer several times and in turn the system responded whether the answer was correct or not.

Moodle managed navigation between the two system levels and applications. Navigation in the system was enabled by hyperlinks in the form of a list of modules, list of chapters, list of tools inside the modules, and path/locator, which changes dynamically according to the chosen link in the hierarchy.

An advantage noted by the authors was the loading speed of the web pages. It was important for them to avoid unnecessary processing of webpages because the video with the instructions had to be loaded fast. The video with the interpreter was encoded as streaming media and put on a dedicated server to speed up streaming time.

Testing of the system was done in two ways: pedagogical and usability. Pedagogical test evaluated the efficiency of e-learning. Pedagogical tests gave the users a pre-exam before e-learning and a post-exam after to gauge the learning effect

using the e-learning materials. Usability of the system used a Software Usability Measurement Inventory (SUMI) questionnaire [57].

Results of the tests participants took before and after the courses show that the participants were able to successfully use the e-learning environment with the adapted materials and learn from them [33].

The project goal was similar to ours whereby we intended to increase the level of computer literacy amongst Deaf people using ICDL multimedia-supported material. We only differ in terms of the use of the World Wide Web to distribute the e-learning materials. This projects provided insight into the design requirements for ICDL lesson content. We adopt the projects approach to design learning material whereby all audio information was represented visually in sign language videos. We also note that the navigation used in the learning material was kept simple which guides us in our work.

We mentioned in Section 1.2 that the Deaf community use SASL as their primary language. This provided insight to providing access to e-learning materials in the Deaf learners' primary language viz. SASL.

2.8 SignSupport

Researchers from the Computer Science departments at both University of Cape Town (UCT) and University of Western Cape (UWC) have had a long term involvement with DCCT spanning over 10 years. The SignSupport project originated from UWC Computer Science research group Bridging Application and Network Gaps (BANG) and DCCT in collaboration with Delft University of Technology. In this section we discuss the evolution of the SignSupport project.

2.8.1 Looijesteijn's Design

A PC mock-up, designed by Looijesteijn in 2009, implemented the telecommunications solution to be used by a Deaf person to communicate with a hearing doctor using SASL and English text respectively [62]. The user requirements at first were to develop a communication solution that allowed Deaf people to interact with other

Deaf people in their social circles rather than with hearing people [62]. Results from generative sessions targeted communication problems experienced by Deaf people that arose and were studied in a general manner to devise a solution that was appropriate for the needs of a Deaf person at a hospital.

The PC mock-up worked as follows [62]:

1. The mock-up asked a Deaf person questions in SASL.
2. After the Deaf person answered the questions, the answers were presented to a hearing doctor in plain English text.
3. The doctor read the summary of symptoms and responded using a lookup dictionary.
4. The Deaf person then watched the corresponding SASL video of the response

The PC mock-up was implemented on a mobile platform in the next iteration.

2.8.2 Mutemwa's mobile prototype

The second iteration of SignSupport was a mobile prototype designed by Mutemwa in 2010 that allowed a Deaf person using SASL to convey their medical conditions to a hearing doctor face-to-face in the office [73]. The prototype first has a Deaf person answer a series of questions shown in SASL videos. The prototype then produces English text representing what the Deaf person has defined and can be handed to the doctor to read what the problem is in plain English [73].

The mobile prototype was designed as a request by Deaf users after engaging with Looijesteijn's design. The prototype required a mobile phone with a data connection running a browser that supports Small Web Format (SWF) with the intention to run the system within the browser instead of using a third party media player to make it easier to develop and run [73]. SASL videos were embedded inside Extensible Hypertext Markup Language (XHTML) web pages using Adobe Flash. The SASL videos were loaded with the help of a content authoring tool which helps to populate video in a context free manner that allowed for multiple scenarios to be added as needed [73].

There were some issues that the prototype needed to address. The implementation of the prototype only addressed communication in one direction: from Deaf patient to hearing doctor. The doctor could not respond to the Deaf patient solving only half of the communication barrier. The other issue with the prototype was that it was only developed for the Symbian S60 operating system and was not generalized. In terms of usability problems, the limited number of questions that a doctor could ask a Deaf patient and lack of detail in the summary screen hampered its functionality.

Aside from the technical and design problems, the communication domain (patient-doctor communication domain) chosen for the study proved to be vast and difficult to study. In order to create a lookup dictionary to support the actions of the doctor, a communication plot of the domain had to be mapped. This proved to be a challenging task, at the time, that could not be solved in the mobile space because of the limitations of an application designed for a cellphone.

2.8.3 Chininthorn's design

The third iteration of SignSupport was redesigned by Chininthorn, an industrial design engineer from Delft University of Technology. The design follow-up incorporated many attributes from the previous two designs discussed above. The fundamental difference of this design was it was for a pharmacy context. The reason for the context change was that the previous communication domain, Deaf patient to hearing doctor, was too large to encompass all the conversations that could take place [28]. The pharmacy context was small enough to study most of the conversations that take place and big enough to form a meaningful conversation compared with the doctor context.

In this pharmacy context, conversations were pre-recorded SASL videos and stored on the phones memory card. Chininthorn's primary objective was to design a communication aid for pharmacists and Deaf people. In the pharmacy context, Deaf patients were at a high risk because they could take medicines given to them incorrectly. This is often the case because of a breakdown in or lack of communication during the dispensing of medicines process in the treatment cycle [28]. The

communication aid addresses four key issues raised by Deaf participants during data collection and they are as follows:

1. Explanation of the medical condition.
2. Dosage forms and quantity.
3. Time of day and frequency of dosage.
4. Vibrating alarm alerts as a reminder system.

A new design methodology called Vision in Product design approach [50] was used as a guide to tackle design tasks as well as incorporating human centred design approaches to involve all the users of the product (Deaf patients and pharmacists).

2.8.4 Motlhabi's prototype

Motlhabi's iteration of SignSupport was still a communication application that worked on a mobile device. He incorporated a personal reminder feature that alerted patients when it is time to take their medication or when they are about to run out of medication. The design took advantage of a limited communication domain which he defined as a public hospital pharmacy [70, 71].

In this version of SignSupport, a pharmacist was able to share pharmaceutical instructions with a Deaf patient without the pharmacists needing to learn or understand SASL. It made use of pre-recorded SASL videos to communicate with a Deaf patient and English text to communicate patient information to a pharmacist.

The prototype works as follows: A Deaf patients hands over a paper prescription and a device running SignSupport with SASL videos loaded on the device. The pharmacist reads the paper prescription and interacts with SignSupport by inputting medical instructions relating to the patient's illness, medicines to take, dosage amounts and their frequency of ingesting [71].

Motlhabi chose to use pre-recorded sign language videos as opposed to avatars and automatic sign language translation because they did not guarantee enough accuracy for medical use. This decision was based on a study by Ghaziasgar and

Connan who identified that only 60% of signs can be successfully and consistently recognised [41].

The problem with Motlhabi's prototype was that the content was static and could not be changed without the help of a programmer. It also focussed on a finite number of illnesses and types of medication which is not the case in reality and the design was not extendable to other limited communication domains.

2.8.5 Shortcomings of previous versions of SignSupport

In previous versions of SignSupport (see Section 2.8) Mutemwa's version made use of a content authoring tool to allow multiple scenarios to be loaded on the mobile prototype as needed [73]. Subsequent iterations by Chininthorn [28] and Motlhabi [71] did not implement a content authoring tool thus constraining the flexibility and extensibility of the design. It limited the design to one scenario of the pharmacy context with a finite set of illnesses and medications dispensed. We found this constraint far too restrictive because once the list of medications and illnesses was defined, it could not be amended without a programmer. In our design, the content of the lessons was contained in the e-Learner manual which was developed by Computer 4 Kids (see Section 1.3).

Using the information from previous design iterations of SignSupport, we identified that the new system design iteration will need to address two things:

1. Content creation
2. Content consumption

Content creation

Content creation was identified as a bottleneck to Motlhabi's prototype. A programmer would be needed to change the content in the prototype such as adding a new type of medication or illness. This bottleneck could be addressed by designing and implementing an authoring tool to create content for our application context. The authoring tool would allow creation of different scenarios unique to the context, similar to Mutemwa's prototype. Authoring new content would not need a

programmer. We discuss content creation in Chapter 4.

Content consumption

Content is consumed by the mobile prototype similar to Motlhabi's prototype [71]. We use the term *content consumption* to define the site/place or system where lesson content is used. The content will be in the form of pre-recorded SASL videos and images that represent the instructions of the lesson. Details of the design of the mobile prototype are discussed in Chapter 5.

2.8.6 Proposed version of SignSupport

This version of SignSupport examines another application context: Deaf adult computer literacy training. We established from Mutemwa's mobile prototype that to manage multiple scenarios in the communication domain, there is a need for a content authoring tool to allow loading of SASL in a context free manner and independent of implementation platform.

2.9 Summary and applicability to other chapters

Our work was pursued in cycles of community based co-design (CBCD) (the approach is described in Section 1.4). These are documented chronologically in Chapters 3 through 8. Information about context was described in the next chapter and reflection in each cycle was informed by work is discussed here.

In Section 2.2 provided the context for our work, as we are working in a low resourced environment. In addition it highlighted the difficulties of doing research in communities where researchers and their participants come from different context. We mentioned our approach to limit the chances of a failed solution by adopting a community based co-design approach with multidisciplinary collaboration between Deaf subjects, domain specialists and researchers.

Section 2.4.1 highlighted the approaches to developing literacy amongst Deaf people. We identified that literacy development moves across languages and cultures in a *bilingual-bicultural* approach. In Section 2.4.2 highlighted the situation of

literacy amongst Deaf people in South Africa due to unequal access to education. We also see that the use of SASL as the primary language and use of English as the secondary language is beneficial.

The sign language video requirements that were discussed in Section 2.5 highlighted the requirements for intelligible sign language video mobile phones. In addition, the minimum requirements as stipulated in the ITU-T document in Section 2.5.2 guide us in the sign language video specifications that we used to record SASL videos for our system in sections 4.3.3 and 6.3.3.

The e-learning and m-learning environments mentioned in Section 2.6.1 and Section 2.6.2 respectively provide insights into learning environments and design of e-learning materials for Deaf learners. The projects DELE and AMobiLe highlighted the authoring of e-learning materials by domain specialist (teachers and tutors). It informs the design of our authoring tool in Chapter 4 and its refinement in Chapter 6 by working with a domain specialist who we introduce in Section 3.1.1.

We gather more design insights from project DISNET in line with our goals to use multimedia ICDL material to support computer literacy. This informs our design and recording of SASL learning material videos in Sections 4.3.3 and 6.3.3.

SignSupport in Section 2.8 provided the scope for the area we are working in based on the continued engagement with DCCT. Our project is a continuation of SignSupport in the application context of computer literacy training. The previous iterations of SignSupport provided the insight into our methodology of CBCD cycles (see Section 1.4) while working in a multidisciplinary project. It also provided insights into action research reflections at the end of our cycles.

Chapter 3

Computer Literacy Teaching

Our interaction with DCCT and the computer literacy teaching began in March 2013. We actively participated in the classes by assisting the teacher – who we shall refer to as facilitator henceforth – (see Section 3.1.1) with teaching the Deaf learners. We were introduced to the five DCCT staff members who took the classes given by the facilitator. We observed the classes and collected data through observations and conversations with the facilitator throughout the field study. We discuss our engagement in the computer literacy training in this chapter in the sections.

3.1 Computer Literacy classes

The computer literacy lessons were taught using the International Computer Driving Licence (ICDL) approved curriculum, e-Learner, which has two versions: school and adult. The adult version is taught at DCCT [25]. The curriculum is developed by a Cape Town based company, Computer 4 Kids (see Section 1.3). The goal of the computer literacy classes (e-Learner classes which we introduced in Section 2.3) is to equip the Deaf learners with computer skills that will result in the learners taking assessments to get the e-Learner certificate. Achieving the e-Learner certificate, the Deaf learners progress to the full ICDL programme that will result in them receiving the ICDL certificate upon completion. In the next sections, we introduce the facilitator and Deaf learners, provide an outline of the e-Learner course and its lesson structure, the classroom setup, lesson dynamics and a discussion of the

observations.

3.1.1 The facilitator

The facilitator has had a long term involvement with DCCT starting in 1998. From our informal conversations with the facilitator, we found out her role began as an English teacher in the *Adult Literacy Programme* at DCCT in the early days of her involvement. Presently her involvement with DCCT as a facilitator for the e-Learner classes and a research collaborator with Computer Scientists from UCT and UWC involved in the SignSupport project (see Section 2.8).

As we had more conversations, we learned from the facilitator that prior to the start of the e-Learner classes in the middle of 2012, the programme offered at DCCT was the EqualSkills programme. The EqualSkills (see Section 2.3) had four DCCT staff members receiving certificates once they had completed it. Since then, one staff member has left DCCT and moved to Johannesburg.

The e-Learner classes were conducted on Wednesday afternoons in 2013 and were changed to be on Thursday afternoons in 2014. All the classes were conducted based on the schedule of the facilitator and could only happen when the facilitator was available or had left some work where we would supervise in her absence. As this was not the facilitator's only job (pointed out in informal conversation with the facilitator), the period from June to late July and other weeks in the year, teaching of new content was generally temporarily halted, pending the return of the facilitator. This is because of the difficulty to find a replacement and lack of funds to hire an interpreter.

Subsequent conversations with the facilitator and participating in the computer literacy classes (see Section 3.1.5) provided insight into how Deaf people learn.

3.1.2 The Deaf learners

We were introduced to the five Deaf learners who were all DCCT staff members by the facilitator. Three of them were female and two were male with an average age of 38.4 years with grade 12 as the highest education level where the average Deaf

school leaver has a written language comprehension ability of a hearing child of eight [10]. However, the Deaf learners are functionally literate [9] with compromised text literacy skills due to unequal access to education opportunities in Section 1.1.

Three of the Deaf learners work as community development assistants, one as a HIV/AIDS Counsellor and the other as the audiology and technical assistant. Three of the learners had received the EqualSkills certificate prior to beginning the e-Learner training.

3.1.3 Course and Lesson Structure


The e-Learner curriculum is modular and progressive over seven units. The units are similar to the modules in the ICDL programme but contains simplified content. The e-Learner curriculum is provided in two components: A manual containing the lesson instructions and a piece of software contained in a compact disc (CD) that is loaded on the computers to provide templates and lesson resources. The instruction manual is used by the facilitator and the Deaf learners to interact with the software. The units in the e-Learner are as follows:

1. IT basics
2. Files and folders
3. Drawing
4. Word processing
5. Presentations
6. Spreadsheets
7. Web and Email essentials

These units are composed of lessons in the following categories: Orientation, Essential and Supplementary. Lessons in different units overlap. For example, a lesson in the unit IT basics may also appear in the unit Files and Folders. This allows for the learner to revisit a lesson or skip it having completed it before. All the lessons in the e-Learner have the same structure. The lesson structure is as follows:

1. Integrated activity – A class discussion about the lesson content.
2. Task description – A brief overview of the work the learners will perform.
3. Task steps – The individual tasks that the learner must perform to complete the lesson.
4. Final output – A diagram showing what the learners are expected to produce after performing the task steps.

6


INTEGRATED ACTIVITY

In order to promote relevant discussion, the following questions are posed by the educator to the learners:

- **How many people, do you think, are infected with HIV?**
- **How many people are becoming infected with the disease every year?**
- **How can studying statistics help us to combat this disease?**

A short discussion takes place about what HIV / AIDS is and how we can help to fight this disease.

Explain to the learners that today they are going to work with statistics about HIV/AIDS and graph information. They are then going to analyse the information and write about what they have learnt.

Task: Create spreadsheets of HIV/ AIDS statistics. Graph and analyse the information.

1. Double click on the **e-Learner** shortcut on the desktop.
2. Click on the relevant **volume number** and **lesson number**.
3. Click on the website hyperlink under the **Website Linx – Online** heading or the **Website Linx – Saved** heading.
4. Access the AIDS Statistics website
5. Study the regional HIV/AIDS statistics (*Note to educator: Ensure that learners know what is meant by Sub-Saharan Africa*)
6. The page which loads will look like this :




Figure 3.1: The structure of the lesson, “Studying Stats - HIV/AIDS” obtained from the e-Learner manual.

Figure 3.1 shows the first part of the lesson structure containing the integrated activity, task description and task steps. At the top of the lesson are the instructions of the integrated activity that tell the facilitator to lead a classroom discussion on the topic of the lesson. The instructions provide a guideline on how to direct the

classroom discussion by posing a series of questions. The questions try to elicit certain information from the learners. Following the integrated activity is the task description which contains information for the overall tasks that the learners will perform. The task steps are a numbered list of instructions that the learners perform. The number of task steps vary from lesson to lesson. Figure 3.2 shows the difference in the number of task steps between two lessons in the e-Learner manual. The final output is on the last page of the lesson. It is a diagram (see Figure 3.3) showing what the Deaf learners need to produce when they finish performing all the tasks. All the content in the e-Learner manual is signed, by the facilitator, to the Deaf learners in SASL during the class session.

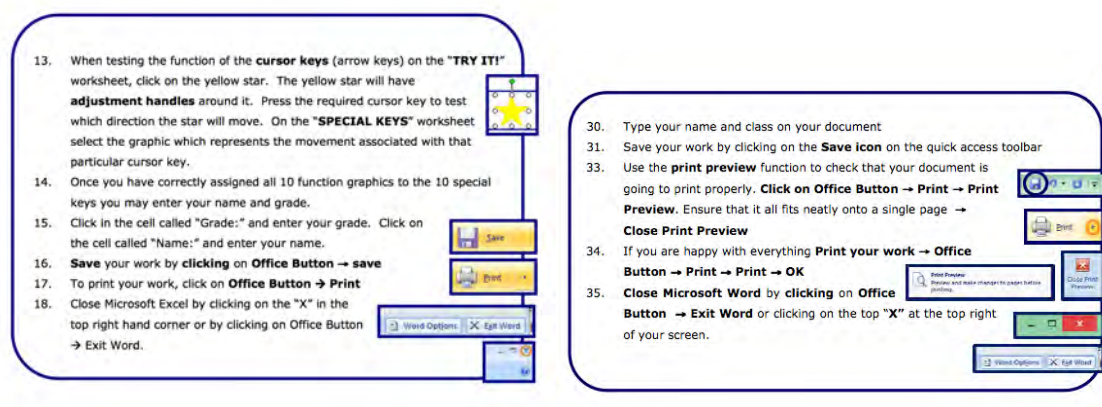


Figure 3.2: A comparison of the length of the e-Learner lessons. On the left, the lesson Special Keys has 18 task steps. On the right, My Organisation lesson has 35 task steps

3.1.4 Classroom setup

The classroom has six computers arranged on three tables in a U-shaped arrangement. There is a server at the front left with a flip-board on a stand and two whiteboards on the left and on the right (see Figure 3.4). There is a data projector, mounted overhead, that uses the server to project lesson materials on to the wall. The U-shaped configuration is ideal to allow the learners to have a clear line-of-sight to view the front of the classroom where the facilitator stands and signs. The seating arrangement also allows the Deaf learners to see each other which is crucial for class

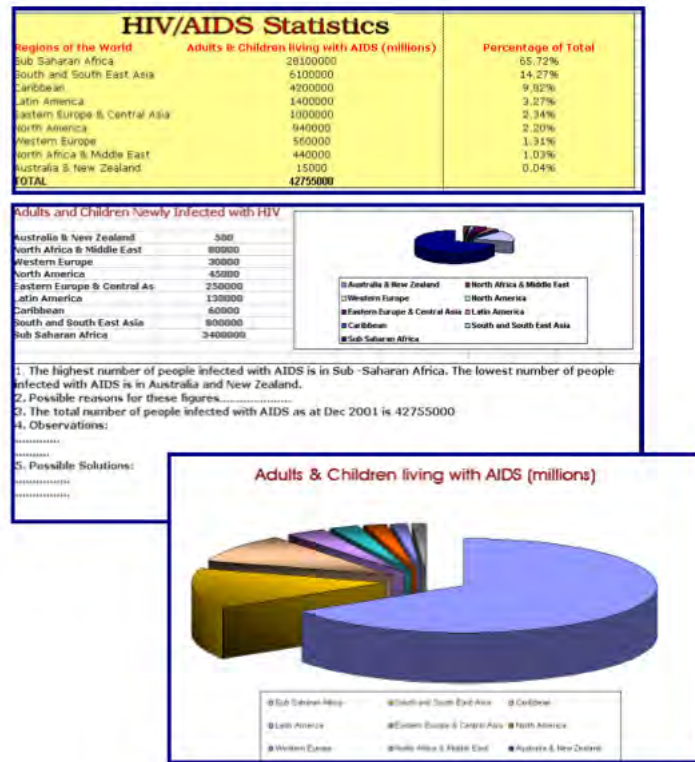


Figure 3.3: The final output of the lesson “Studying Stats - HIV/AIDS” obtained from the e-Learner manual. At the end of the lesson, the learners are required to come up with the above result once completing all the task steps.

discussions, contributions from other learners and questions.



Figure 3.4: The classroom setup viewed from the back of the classroom

Each computer, except for the server, is running a copy of the operating system Microsoft Windows 7. All the computers have a copy of Microsoft Office 2007 and e-Learner Adult version 1.3 loaded. The e-Learner software is used by the Deaf learners to access the lesson templates and resources.

3.1.5 Lesson and classroom dynamics

In this section we discuss themes that arose from the various lessons we observed and participated in. These themes are organised in the subsections below.

Teaching methods

Although the lessons in the e-Learner manual have the same structure, the teaching of the lessons is never the same. The facilitator adapts the teaching method and content of the lesson to make it relevant for the Deaf learners. In lessons that required use of different Microsoft Office programs (Word, Excel and Powerpoint), the teacher would first introduce the different programs of Microsoft office then proceed to open the program. Once it is open, the facilitator goes through each

and every tool(icon) in the program showing the function of each. This generally takes up the whole lesson duration and the Deaf learner would only get hands on experience to perform the lesson tasks in the next class session which would be the following week.

Images play a big role in the teaching of the computer literacy skills. The facilitator makes use of the data projector to display open documents in Microsoft Word, Excel or Powerpoint. There are numerous times when the facilitator points at the projected image of the computer application that is being used in the lesson, pointing out buttons and icons to click and lists to scroll through.

Currently the procedure to teaching Deaf learners is demanding on the facilitator. There is only one copy of the e-Learner manual that is used in the class. The manual is the instructor's version of the e-Learner and not to be used by the learners because of the low literacy of the Deaf learners to follow the task steps. The teaching procedure is as follows:

1. Read the instructions of the lesson from the e-Learner manual
2. Understand the information of the lesson
3. Get the attention of the Deaf learners using various means discussed in the section below.
4. Sign the instructions to the Deaf learners.
5. Proceed to use the mouse and keyboard to demonstrate to the learners using the data projector what has just been signed.
6. Move around the class to check if the Deaf learners have understood and implemented what they have been shown.

During our participation in the classroom activities, we are involved in controlling the mouse and keyboard of the projected computer screen. Our role in the lesson is the facilitator's assistant. This adds an additional step for the facilitator while teaching because we have to be told what to do. Therefore, it makes it even longer for the learners to receive the instructions. In this scenario, the facilitator first

signs to the Deaf learners and then voices to us (Computer Science students) the instruction to perform on the computer so that the learners can have an example to see and understand.

In addition, when a Deaf learner need additional assistance, the facilitator has to navigate through the limited space in the computer lab to get to the learner. Her free movement is restricted which further adds to the frustration of teaching.

Attention getting techniques

In order to gain the attention of all the Deaf learners, the facilitator waves her hands in front of the learners. This is necessary in order for the facilitator to explain a concept or give instructions to Deaf learners due to the visual nature of sign language. This is a distinguishing factor between Deaf and hearing learners called divided visual attention. Hearing learners can simultaneously listen to instructions is being given and look at their computer monitors without looking up. Deaf learners cannot watch the SASL signing and look at their computer screens at the same time. So we need to gain their eye contact first before beginning to sign.

English vocabulary

Deaf learners primarily use SASL as their principal language of communication. English users bring all the necessary vocabulary to the task of computer literacy skills learning. Deaf learners do not have this English vocabulary to rely on, hence they are learning English vocabulary and ICT skills at the same time. English vocabulary in computer literacy classes has to be broken down by either making use of synonyms, definitions or descriptions. For example, in a lesson observed, the facilitator broke down the word “duplicate” into two separate words “copy and paste” after which the Deaf learners associated copy and paste with their respective signs in SASL.

In the lesson observed, “Studying Stats - HIV/AIDS”, the facilitator explains the concepts *statistics* and *global* using simpler words like *numbers* and *worldwide* respectively to help the learners understand. To paint a picture of the location of Sub-Saharan Africa (see Figure 3.5), the facilitator sketches a map of Africa on a

flip chart pointing out the location of the Sahara desert and indicating the area below the desert as Sub-Saharan Africa. By using the analogy of a *submarine*, the facilitator isolates the prefix *sub* in submarine to simplify it to *below* whereby the learners now understand the link between *sub* and *below*. In addition to teaching English vocabulary, concepts from Geography are introduced. A lack of general knowledge because of poor language skill and low literacy skills.

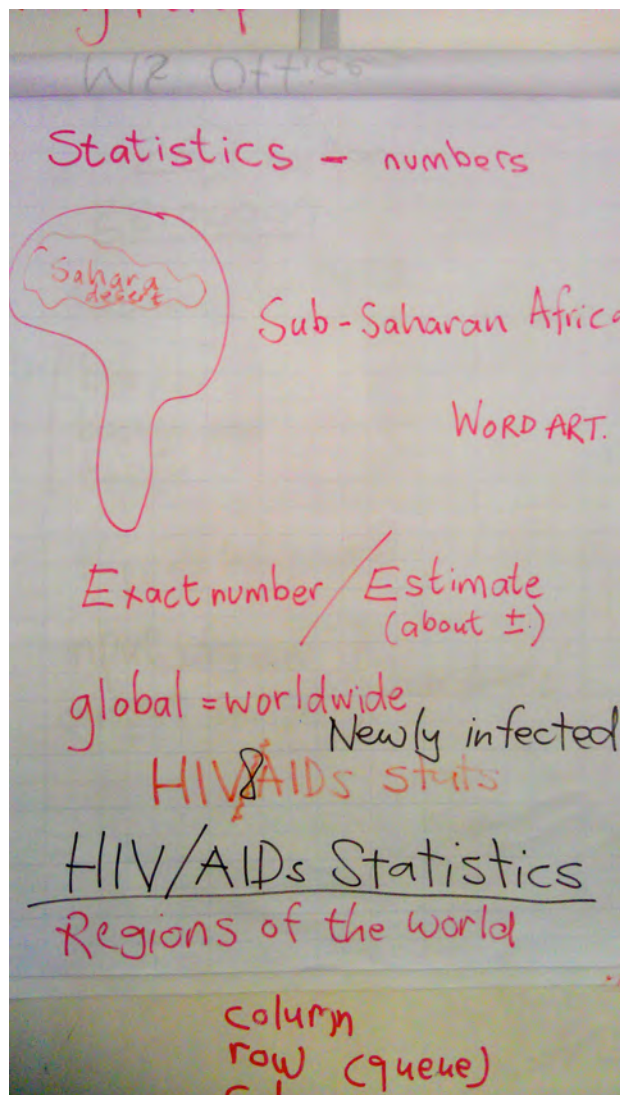


Figure 3.5: A breakdown of the concepts in the lesson “Studying Stats - HIV/AIDS”

Learning Pace of the Students

We observed different work rates from the Deaf learners during our class participation. The faster Deaf learners usually finished their tasks earlier and often spent time waiting for the slower learners to catch up. The three faster learners easily and quickly understood the instructions better than the slower learners they would implement them because of their prior exposure to EqualSkills programme (see Section 3.1.2). The pace of learning was hence dictated by the slower learners and the facilitator was forced to teach at a slower pace to accommodate the slower Deaf learners. When a slow Deaf learner doesn't understand something, all learners have to be interrupted. This puts pressure on the slower learners and makes it boring for the faster learners.

3.1.6 Existing Technology Usage

During our field study, we observed the Deaf learners using various mobile phones. The mobile phones identified ranged from feature phones to smart phones. One learner had two smart phones: a HTC running Android OS for work and a Blackberry for personal use. Two other participants had Nokia feature phones with QWERTY keyboards. In addition, the Deaf learners do not have computers or laptops at home and at work, they use old computers hence their limited experience.

At the time of the e-Learner lessons, the Deaf learners participated in the evaluation of Motlhabi's version of SignSupport (See Section 2.8.4), which introduced touch-screen Android devices (Samsung Galaxy S2), new to some learners who had non-Android devices. The exposure to new technology introduced touch and swipe gestures which could prove useful for our proposed intervention.

3.2 Analysis and design implications

There are many aspects to cognitive functioning such as remembering, reasoning, decision making, problem solving and learning. Cognition has also been described in terms of the context in which it takes place, the tools that are employed, the artefacts and interfaces used and the people involved [89, p. 66-67]. Some of these cognitive

activities have been exhibited throughout the class environment. Understanding cognitive activities in the context as they occur, as it happens in everyday life [51], can uncover structures in the environment that support both human cognition and reduce cognitive load [89, p.91]. We identified different types of cognition which sought to help us breakdown the class environment.

We use a distributed cognition approach [89, p.91] to understand the classroom environment. Distributed cognition studies cognitive phenomena across individuals, artefacts and internal and external representations [51, 52]. It defines a cognitive system which entails:

- Interactions among people (communication pathways)
- The artefacts they use.
- The environment they work in.

We define our cognitive system as a computer literacy class where the top-level goal is to teach computer skills to Deaf learners. In this cognitive system we describe interactions in terms of how information is propagated through different media. Rogers *et al.* [89, p.92] describe it as how information is represented and re-represented as it moves across individuals and through the array of artefacts used (e.g. books, spoken word, sign language, gestures and pictures) during activities.

In the computer literacy class we have two communication pathways. These are the channels by which information is passed between people. Communication in the class is via verbal and signed language. The verbal communication is between the facilitator and the assistant(researcher) while sign language (SASL) communication is between the facilitator and the Deaf learners, and between the Deaf learners themselves.

Propagation of representational states defines how information is transformed across different media. Media here refers to external artefacts (paper notes, maps, drawings) or internal representations (human memory). These can be socially mediated (passing a message verbally or in sign language) or technologically mediated (press a key on a computer) or mentally mediated (reading the time on a clock) [89,

p.303]. Using these terms we represent the computer literacy class cognitive system showing the propagation or representative states for the teaching methods (see Section 3.1.5) in the diagram below (see Figure 3.6).

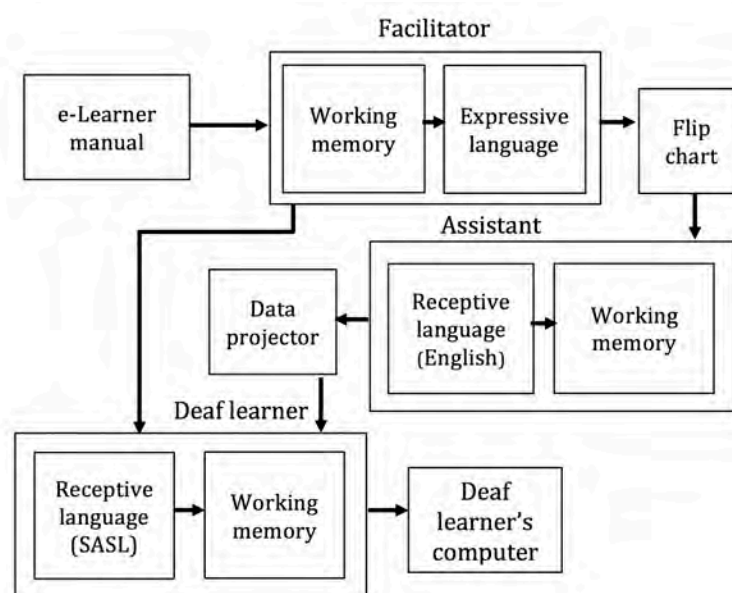


Figure 3.6: A diagram showing the propagation of representational states for the teaching method to deliver a single instruction to the Deaf learners. The boxes show the different representational states for different media (e.g e-Learner manual, facilitator's working memory, flip chart) and the arrow shows the transformations.

By representing the teaching method in a diagram we discover that the task of teaching Deaf learners is far from being a simple task, involving a set of complex steps. Instructions are propagated through multiple representational states, verbally when interacting with the assistant, visually when interacting with the Deaf learners and when written on the flip-chart and mentally in both cases.

The design implications would be to reduce the number of steps involved to deliver instructions to the Deaf learners. A solution would be to deliver the lesson instructions in SASL videos, effectively removing a number of representational states, approximately four. The lesson instructions will be pre-recorded videos of lesson content. The SASL videos also eliminate the need for the assistant and the facilitator to deliver the lesson instructions.

Our design targeted Deaf learners only, going against Universal Design principles

[63] which have their roots in architecture. The design principles strive to ensure environments are useable by the broadest spectrum of people [91] without the need for adaptation or specialised design [81].

3.3 Summary

In the computer literacy classes, we have identified that the teaching methods are demanding for the facilitator. Analysing the classes using a distributed cognition framework aids in understanding the cognitive load on the facilitator and diagrammatically shows the number of representational states involved in the process of teaching. The insight obtained from the distributed cognition analysis helps make a design consideration that would see a reduction in representational states which in turn would take some stress off the facilitator.

The limiting space of the computer lab identified in Section 3.1.5 inhibited free movement which frustrated the facilitator trying to reach the Deaf learners. On the other hand, learning computer literacy skills becomes a lesson in both computer literacy and English vocabulary. If Deaf learners could read the instructions in the e-Learner manual then they could work at their own pace. Poor text literacy amongst Deaf learners means the need for SASL instructions thereby allowing them to learn in their preferred language.

The slow pace of the class learning, dictated by the slow learners, prevents faster learners from progressing ahead which might frustrate them. It prevents the learners from working at their own pace.

From the findings of the computer literacy training we move to address the issues of lesson content creation. The implementation is discussed in Chapter 4.

Chapter 4

Cycle 1 - Authoring tool

4.1 Diagnose

In Chapter 3, we observed and participated in the computer literacy classes. We were also introduced to the facilitator and the Deaf learners. With a better understanding of the computer literacy classes, coupled with the shortcomings of previous versions of SignSupport (see Section 2.8.5), we sought to create an appropriate solution.

We revisit our support theme. In the results in Chapter 3 we see intermediated supported learning emerging in the e-Learner classes. Deaf learners depended on the facilitator for delivery of learning content. In addition we identified that due to language barrier, Deaf learners had limited access to e-learning materials. We expand our research question, *“What are the potential ways a mobile phone can reduce dependency on teachers?”* Dependency on the facilitator would be reduced by using multimedia supported learning system (see Section 1.5.5) which we intended to apply to the e-Learner classes. The benefit of the using the system to support the traditional means of learning and present an effective way of delivering content, enabling the facilitator to focus on parts of the lesson critical to the understanding of the subject. However, using the multimedia supported learning system needed the facilitator create content for the Deaf learners. This would need a programmer for content creation. Dependency on the facilitator takes on a new form: The facilitator depending on programmer to author content in addition to dependency by the Deaf learners.

Content creation bottleneck identified in previous designs (see Section 2.8.5). To address this bottleneck and to also reduce dependency on the facilitator we introduced an authoring tool. The authoring tool, a software system, to be used by a domain specialist, in our case the facilitator, to create and appropriate learning materials for the Deaf learners. The authoring tool fits into our research We describe the details of our authoring tool in Section 4.2.

The workload demands on the facilitator while teaching the computer literacy classes would sometimes lead to frustration for the facilitator and/or learners. It involved multiple complex steps to deliver instructions which increased the cognitive load on the facilitator (see Section 3.2), by switching between her receptive language (English) and then translating into an expressive language (SASL) which the Deaf learners understood while at the same time gaining their attention using various methods (see Section 3.1.5). Due to the poor text literacy of the Deaf learners, they are unable to read the e-Learner manual which further necessitates the need for instructions in their preferred language, SASL.

In addition, the classes being organised around the schedule of the facilitator resulted in long periods of time where no learning occurred (see Section 3.1.1). The consequence of this gap in learning made the next lesson a revision of past lessons thereby reducing the number of lesson sessions to introduce new concepts.

4.2 Plan – Prioritising content creation

A crucial decision in planning was whether to translate all the lesson content into sign language videos or only translate sections of the lessons. There were two scenarios that the facilitator pointed out that would affect the design of the authoring tool and subsequently the design of the mobile prototype in later cycles (see Chapter 5). The scenarios identified were as follows:

1. To have all the lesson content delivered through of the medium of SASL videos and images.
2. To have a class discussion conducted by the facilitator and the lesson tasks provided in SASL videos and images.

We chose the first option. Using the lesson structure in Section 3.1.3, we chose to record all sections of the lesson structure. The integrated activity was changed to a series of videos providing definitions and explanations about the lesson content. The reason for the first scenario was that for the potential system (authoring tool and mobile prototype) to stand alone, all the content would need to be in SASL videos with the accompanying images. The scenario choice was also in line with our theme of *support* which underlies the research questions we posed (see Section 1.6). In addition, the unavailability of the facilitator and the lack of a substitute for periods of the year further motivated our choice for the first scenario.

The authoring tool's goal was to assist a domain specialist, a facilitator, who knows both the computer literacy skills and sign language with the teaching of computer literacy skills using the e-Learner. The facilitator found supervising practical work where Deaf learners were working at their own pace a demanding task. In addition, the Deaf learners had poor text literacy, needing instructions to be delivered in SASL short video clips and diagrams based on the e-Learner manual.

The authoring tool would allow the facilitator to put together practical instructions by assembling the materials, linking them with facilities for learners to ask questions, backtrack, review significant information and so forth which would run on a computer or laptop and output XML data.

To create lesson content for the authoring tool, we planned to record SASL videos of the lessons from the e-Learner manual. We would hire a SASL interpreter to assist us in the recording process in Section 4.3.3. We reviewed the recording procedure used by Motlhabi [71] for his pharmacy context of SignSupport (see Section 2.8) where he used a conversation script. Generating our conversation script for recording required us to translate the e-Learner lesson instruction into SASL. Lessons to be recorded were chosen with the help of the facilitator.

Implementation of the authoring tool system was carried as a project by third year undergraduate Computer Science students at UCT. The students developed authoring tools as part of their course requirements for software engineering. Together with the facilitator, the resulting software was evaluated and certain features and functionality chosen for further development.

4.3 Act

In the design of the authoring tool, we benefited by having the facilitator as a co-designer in the design process. We placed priority on the input that we received from the facilitator who would be an end user of the authoring tool.

Design began with meetings held at UCT with the facilitator. The meetings were used to gather a list of user requirements, most of which we implemented in this cycle. The implementation of the authoring tool was presented as a third year Computer Science project called *Supporting Computer Literacy Training in Sign Language – SCLTSL*.

4.3.1 Supporting Computer Literacy Training in Sign Language – (SCLTSL)

This project was offered to third year Computer Science students at UCT. Eight students in working in pairs undertook this project for a period of two months.

Under our supervision the groups worked to design and implement the authoring tool. Scheduled bi-weekly meetings would keep track of the progress and deliverables for the project. All students were involved in the initial design meeting with the facilitator where a list of requirements, functionality of the system and project deliverables were discussed. In addition, the meeting outlined the requirements for the data interchange format which formed the link between the authoring tool and the mobile prototype in cycle 2 (see Chapter 5). Discussion of the XML structure is in the section 4.3.2.

Essential deliverables for our project were the prototype demonstrations and the final authoring tool systems. From the prototype demonstrations, we would check how well the students understood the user requirements. Each group signed a non-disclosure agreement (see Appendix E) after which they were given access to a copy of a lesson from the e-Learner manual. They would generate a conversation script, a document detailing lesson content in point form in English text that would be recorded into SASL videos with the help of a SASL interpreter. We sent the scripts to the facilitator for verification. Once we received feedback, we simplified the

translation of the scripts. The challenging task was to break down complex words and definitions were simplified to make it easier for the SASL video recording. Once the script was simplified and re-verified by the facilitator the SASL videos recorded (see Section 4.3.3). The lessons that were recorded using the scripts from the e-Learner manual are as follows:

1. O4: Special Keys
2. E6: Files and Media
3. S1: Input and output devices
4. S2: Top ten tools

We chose the lessons above to cover the range of the three categories from the e-Learner manual: Orientation, Essential and Supplementary (see Section 3.1.3). The lessons differed in difficulty; Special keys was the easiest, Input and output devices and top ten tools being moderately difficult and files and media being the harder of the lessons.

The final authoring tool systems were evaluated by the facilitator (see Section 4.4). The best functionality and features identified in the evaluation were taken forward for further development and combined into one authoring tool. The development was done by three students who participated in the project. The new authoring tool was developed over two weeks at the end of November 2013 where we supervised the work being done. The features adopted were the following:

1. User interface with drag and drop functionality: The drag and drop functionality makes it easy to add videos and images with simple click, drag and drop mouse actions.
2. User manual and help functionality: To help new and novice users to troubleshoot and understand the functionality and features of the system.
3. DOM parser for XML interpretation: To verify the syntax of the XML data interchange format.

4. User management system: To manage users who use the system with login credentials.

4.3.2 XML Version 1

We needed an effective means of structuring the lesson content that the authoring tool generated and compatible with our multimedia supported system appropriated on mobile devices. The e-Learner lesson structure (see Section 3.1.3) was uniform across all lessons making it easy to represent the lesson content. We chose XML as our data interchange format to address our

Design of this version of XML format was conducted in two technical meetings with the SCLTSL project groups (see Section 4.3.1) and the facilitator in August 2013 when the facilitator was present for the first meeting for requirements gathering. The result from the first meeting scoped the outline of the e-Learner manual as follows:

- A course is made up of units
- Units contain lessons
- Lesson can be in different units.

The structure of all lessons was identified as follows:

- Integrated activity
- Task description
- A list of task steps
- A diagram of the final output

Additional information obtained was from the facilitator who provided us with a description of the integrated activity section of the lesson. It was a classroom discussion between the Deaf learners and the facilitator (see Section 3.1.3). In the discussion, the following items are highlighted about the lesson:

- Introduce the topic of the lesson.
- Definition and description of concepts or tools used in the lesson.
- Examples of the tools.
- Demonstration of the tools.

Using the information based on the e-learner manual structure, we followed the steps below to design version 1 of XML. The process was as follows:

1. Identify the course, unit and lesson structure.
2. Represent the course, unit and lesson using the tags (course, unit and lesson).
3. Provide the course, unit and lesson with unique identifiers.
4. Identify the sections of the lesson and provide them with tags.
5. Identify what lesson sections are to be represented using video tags
6. Identify what lesson sections need images to accompany the videos and represent them using image tags
7. Identify how to manage lesson assets (images and videos).

The resulting structure of the XML data format (see Figure 4.1) outlined the structure of the e-Learner manual showing its hierarchical structure. A design consideration was to store all the assets of the lessons (videos and images) in a folder. The root folder was named *SignSupport* and had the following sub-folders:

- XML – This folder stored the XML data files of the lessons.
- Shared images – This folder stored the images used in the lessons.
- Video – This folder stored the video files of the lessons.

XML data was an output of the SCLTSL project (see Section 4.3.1). However, the XML version designed here was hard-coded. It was designed as an output for the SCLTSL project groups to test in their implementation. We use this hard-coded version in Chapter 5.

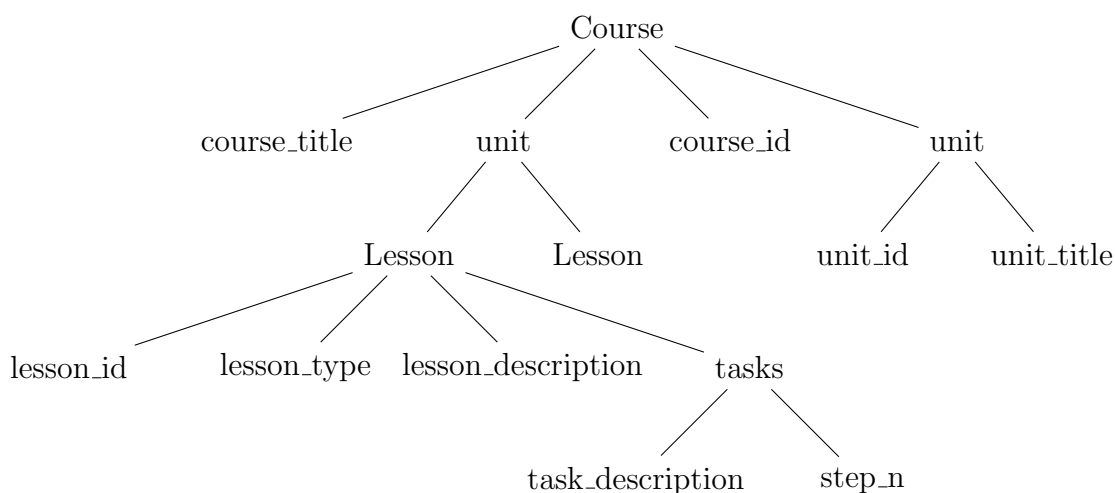


Figure 4.1: Version 1 of the XML data format showing the representation of the course.

4.3.3 Recording of SASL videos

To record SASL video for SignSupport follows a certain number of rules and ethics. A SASL interpreter and a Deaf community member are both involved in the recording process. Recording is done in a room with a neutral background, preferably a studio, with sufficient lighting or with additional lighting supplied. A Deaf community member, who will be recorded, stands in-front of the camera mounted on a tripod. The interpreter is out of the frame, behind the camera. The attire worn by the Deaf community member has to be neutral, black preferably, to contrast with the background colour and the skin of their hands and face.

The recording procedure involved having an interpreter being voiced to or reading the instructions on a conversation script. The interpreter then signs to a Deaf community member the instructions to which the Deaf member repeats the signing. This is repeated until all the instructions on the script have been signed. Separation of the signed instructions is done by writing down the number of the instruction on a whiteboard or paper according to its position on the script and displaying it in-front of the camera while continuous recording. This helps when editing the SASL videos.

Recording of the SASL was done in September 2013. The venue was a meeting room in the Center for Information and Communication for Development (ICT4D) laboratory inside the Computer Science building at UCT. We chose this room because it had a neutral background and sufficient lighting. The interpreter we chose

fulfilled the following criteria:

1. A registered SASL interpreter.
2. A background in education.

We recorded the interpreter signing the instructions from the scripts. In the process of recording, we voiced the instructions from the script and the interpreter signed these in SASL. To identify each instruction and easily recognise it while continuously recording, we voiced the number of the instruction as it appeared on the script. Doing this allowed us to split the video recording into the individual instruction video files and rename the split videos files while editing before removing the audio from the video.

We recorded all the SASL videos for the four scripts created by the students groups for the e-Learner lesson. We later edited the videos, removing the audio on video clip and encoding them using the H.264 video codec and the MP4 container using Adobe Premier Pro CS6. The video frame was 640 by 480 pixels and a frame rate of 25 frames per second (fps) as per the ITU requirements [48].

4.4 Evaluate

We evaluated the authoring tool using a usability study to test its functionality outline in the SCLTSL project specification. The study aimed to test the functionality of the authoring tool with the facilitator as per the project specification given to the groups.

4.4.1 Procedure

Each group of students presented their copy of the authoring tool which they had preloaded before the evaluation. They demonstrated the functionality and features of their authoring tool to the facilitator and project sponsor. The facilitator and project sponsor would then question the group members on their authoring tool.

4.4.2 Results

We review the outcomes of the evaluation based on the use by the facilitator.

Functionality

All groups implemented the basic functionality. One group did not implement the functionality a lesson preview function that enabled the facilitator to review the lesson before exporting it as XML data. One group's authoring tool did not export XML. One group added a XML verification function that checked the XML prior to exporting. The groups implemented a rudimentary version of the lesson preview which the facilitator wanted a refined implementation of it.

Features

Two groups added additional features that the facilitator liked. One of the two groups added a user management system that authenticated a user before using the authoring tool. The other group included a user manual which the facilitator mentioned would be of great use. The user manual included a glossary of terms.

User interface (UI)

In terms of user interfaces, one group had a good user interface as pointed out by the facilitator. The user interface allowed the facilitator to add resources by dragging and dropping the resources on the lesson using a mouse (see Figure 4.2). In addition, the UI came with a help feature that the facilitator found useful. Another group's user interface had many customising features that allowed managing of units. Although the customising features were good, the facilitator mentioned that it looked too complicated because of the numerous dialog boxes one had to go through to accomplish the task.

4.4.3 Discussion of results

During the evaluation of the four authoring tools, the facilitator identified that the user experience and ease of use illustrated in Figure 4.2 was the better than all

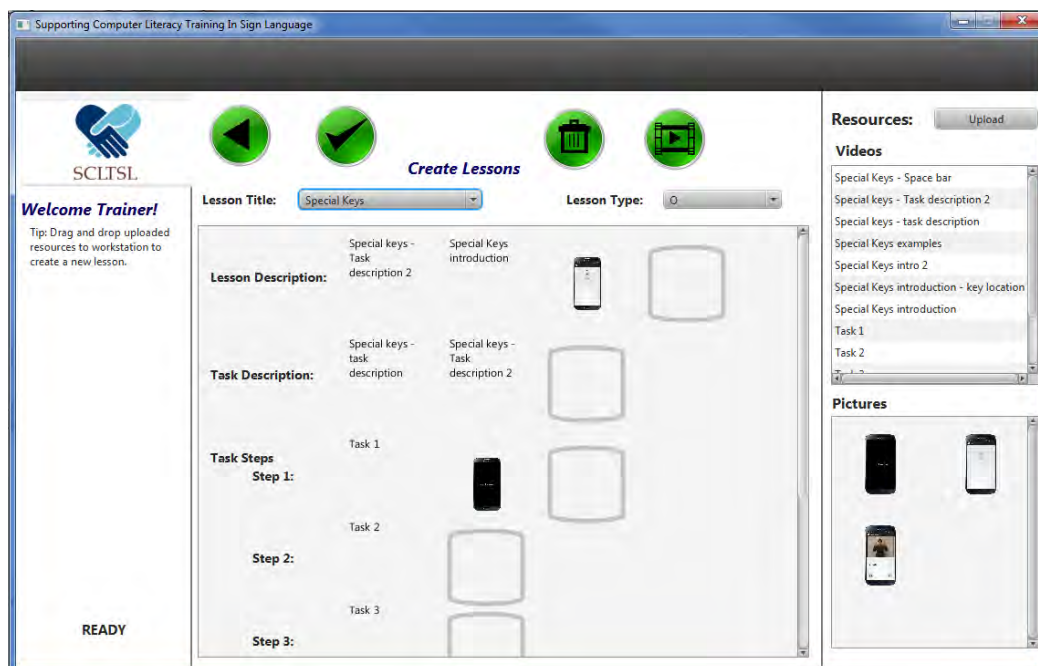


Figure 4.2: The user interface (UI) of the authoring tool with the drag and drop functionality

the three other authoring tools presented. The incorporation of the user manual and help functionality justified the facilitator's decision for choosing that one. The group with the user management and XML verification in their authoring tool had a better implementation of the technical backend of the authoring tool than the other groups. The facilitator wanted the lesson preview function implementation improved which was beneficial to view the authored lesson.

We identified the best features and functionality presented in the two better implementations of the authoring tool (see Section 4.4.2). These were taken further for development to create a new authoring tool in Cycle 3 (see Section 6). The facilitator wanted the lesson preview functionality to be included in the future implementation.

The authoring tools demonstrated addressed content creation for domain specialists. They showed that the dependency that the facilitator had on programmers to author content was addressed to the satisfaction of the facilitator

4.5 Reflect

Prioritizing content creation was a necessary step in order to address the bottleneck that was in the previous two iterations of SignSupport (see Section 2.8.5). In our design, we benefited from having the e-Learner manual which eliminated the need for creating our own learning material. The user experiment by the content creator provided us with insight for the changes in future implementation of the authoring tool.

The uniformity of the structure of e-Learner lessons aided in the design of the XML data format. At first it was a challenge because we need to have a standardized format that represented all the lessons in the e-Learner and the XML tags that needed to be defined. The other challenge was managing the lesson assets (SASL videos and images). Our design decision to store the assets in folders and manually transfer them to the mobile device using a cable simplified our design. In addition, the e-Learner curriculum does not change frequently eliminating the need to transfer lessons over a data network.

The implemented authoring tool allowed the facilitator to create and modify lessons without the need for a programmer. This will allow her to create lessons based on the demands of the Deaf learners.

Recording of the e-Learner lessons into SASL videos was a challenge. It was a tedious and time consuming process. It exposed us to the recording process which provided us with insight into generation of multimedia educational materials.

Once the first step of addressing content creation was achieved, we now progressed to investigate content consumption which was to be handled on the mobile device in the next chapter.

Chapter 5

Cycle 2 - First Mobile Prototype

5.1 Diagnose

In Chapter 4, we looked at content creation which involved designing an authoring tool and XML data format to structure the lesson content. In this chapter we investigate content consumption which we identified earlier (see Section 2.8.5). We refer to content consumption as the use of the lesson content for self study or self-teaching. In this case we use the term, not in a theoretical sense but to distinguish between the two parts of our system where content is created (authoring tool) and where it is used/consumed (mobile prototype).

In Section 3.1.5, we identified different individual working rates of the Deaf learners. Faster learners were impeded by the slow work pace of the slow learners making the class boring and sometimes frustrating for them. This resulted in the pace of the class being dictated by the pace of the slow learners because the facilitator was forced to deliver the instructions at the pace of the slow learners.

Since Deaf learners are text semi-literate they are dependent on the facilitator to sign the English text instructions found on the e-Learner manual, to them in their preferred language, SASL. With this information on learning difficulties for Deaf people, we sought to design and implement an appropriate solution to support their learning.

In Section 3.2 we identified the numerous representational states involved in delivering instructions to Deaf learners. We mentioned that in our design implication

use of SASL videos to deliver instruction would reduce the states. Returning back to our theme of support (see Section 1.5) we wanted to reduce the number of steps by using a multimedia supported learning system appropriated to technology available to the Deaf learners. In Section 3.1.6, we identified the technology capacity of the Deaf learners who used mobile devices which had the sufficient capabilities to support a multimedia supported learning system. In the context of SignSupport, our solution was geared towards mobiles because it was the first point of computing exposure for the Deaf learners.

5.2 Plan – Prioritizing Content Consumption

The Deaf learners would be the sole content consumers on the mobile prototype. A design decision to support content consumption that we needed to reach in planning whether to design a brand new user interface or modify the interface design of the previous SignSupport iteration designed by Motlhabi. We chose to evolve the design of Motlhabi, justifying our decision because of the users experience of the system. Navigation in Mutemwa’s prototype used buttons on a keypad [73]. Interaction in Motlhabi’s prototype was by directly manipulating icons on a touchscreen [71, p. 55]. The icons represented actions that a user wanted to perform. The time needed by a user to relate a keypad button press to the action is greatly reduced on a touchscreen because of the direct manipulation of icons on the touchscreen and the instantaneous feedback.

We investigated the previous version of SignSupport (see Section 2.8.4) that was developed on Android, the mobile operating system (OS). Android supported touch-based gestures on a touch screen, similar to Motlhabi’s implementation.

To avoid data costs, a design consideration was to preload the folder containing the lesson resources to the mobile device’s internal memory (see Section 4.3.2). The alternative design decision would be to stream the lesson content via a network connection which would be costly due to high data costs in South Africa [23] and the socio-economic background of the Deaf people (see Section 1.1). The location of the assets in the folder were defined in the XML data format defined in Section

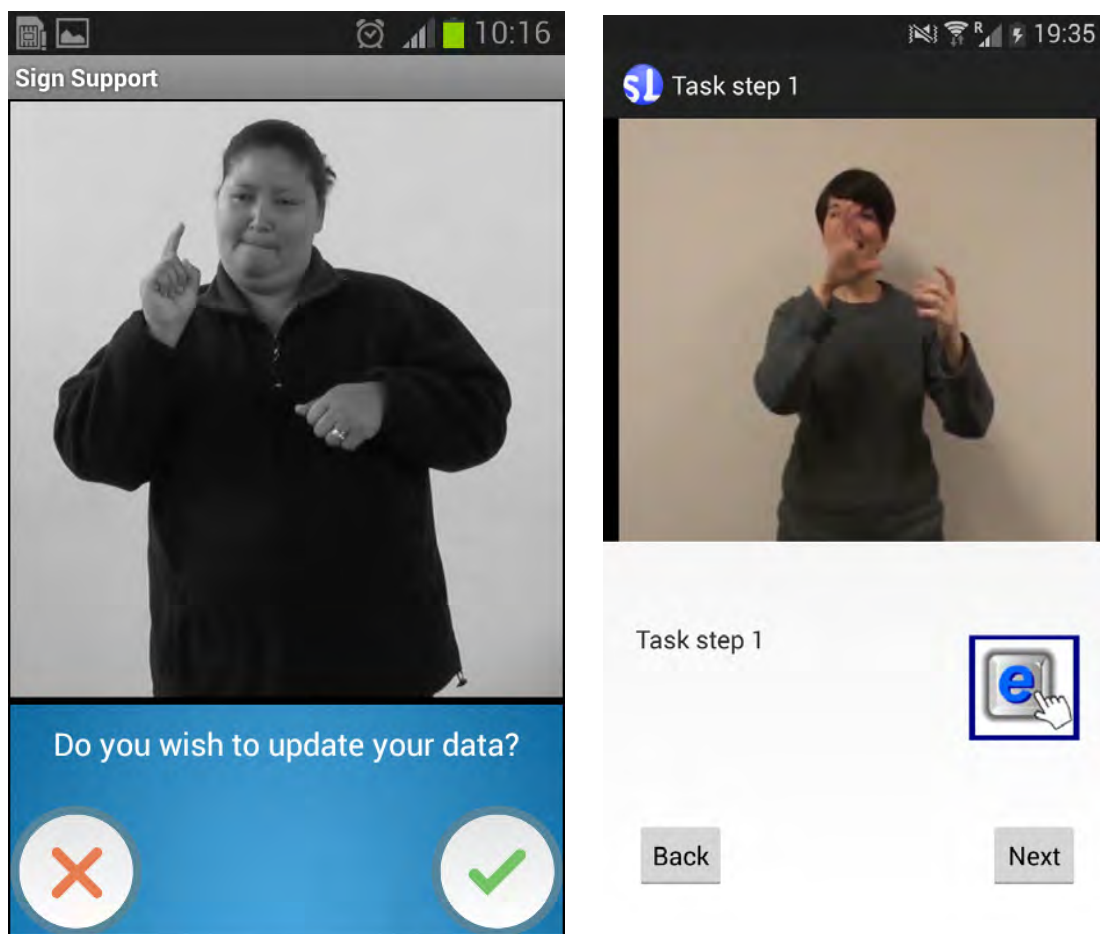


Figure 5.1: The comparison of the screens of the two different versions of SignSupport. The image on the left is Motlhabi’s prototype and on the right is our prototype with an image beneath the video.

4.3.2. Other design considerations are discussed below in Section 5.3.2.

We hoped to make use as much as possible of the existing technology capacity (see Section 3.1.6) because the Deaf learners were experienced users of mobile phones. We found that the Deaf learners used video capable commercially available mobile phones for personal use and had limited access to computers. We hoped to make use of this in a non-entertainment purpose while trying to eliminate costs incurred due to data. If the lesson content could be disseminated over commercially available mobile phones, we believe it would take advantage of this.

Two new researchers joined the SignSupport project in this cycle. One from UCT and the other from UWC. The UCT researcher focussed on the efficiency of parsing a data structure on a mobile device and the UWC researcher focussed on

creating an authoring tool to create content for SignSupport’s generalised contexts of use. The contexts such as pharmacy dispensing and reporting a crime at a police station. Our authoring tool focussed on authoring content for the e-Learner lesson content. Underlying all our overlapping research interests was a data interchange format which structured e-Learner lesson content in our project, efficiently parsed on a mobile device and generalised to the pharmacy and health SignSupport context. Underlining the technical part of our research areas was the need for an efficient data interchange format. We discuss this in more detail in Section 5.3.1. Our research interests overlapped with the two other researchers in terms of a data interchange format. Our context focussed on designing a data interchange format for the ICDL context.

5.3 Act - Implement Design

Design began by investigating SignSupport’s previous interface designs and to optimise the existing technology capacity (See Section 3.1.6). We also made changes to the XML design in Section 4.3.2 following our new list of requirements we needed to fulfil, most of which we implemented in this cycle.

Implementation followed design. The XML data format defined in Section 4.3.2 was re-designed due to a change of requirements discussed below in Section 5.3.1. Development of the mobile prototype involved tweaking the design of the previous SignSupport Deaf user interface. The prototype, in the backend, parsed the new version of XML discussed below (see Section 5.3.2).

5.3.1 XML Version 2

The entry of the two new researchers into the project and our overlapping research interests explained in Section 5.2 motivated us to collaborate in designing our new version of the XML. We first reviewed the original design (see Section 4.3.2) and then investigated JavaScript Open Notation JSON (<http://www.json.org>) as an alternative data interchange format.

We met with the researchers in four technical meetings and later by email cor-

respondence. Our meetings aimed to outline the technical requirements for each of our SignSupport contexts. Their involvement in the project was to collaboratively co-design a data interchange structure that was applicable to all our application contexts of SignSupport. Their context, similar to our project, were collaborative projects with DCCT and the institutions mentioned above and are beyond the scope of this dissertation.

The initial outcome of the meetings was to finalise the choice of the data interchange format: XML or JSON. The starting point was the review of pharmacy version of SignSupport [72] and the version 1 of XML in Section 4.3.2. The design of the first XML version was based on the hierarchical structure of the e-Learner manual. The choice of data interchange format also took into consideration JSON as an alternative data interchange format.

We explored JavaScript Open Notation JSON as an alternative. JSON and XML were text-based and needed to be parsed character by character thus imposing a limit on deserialization speed [93]. JSON makes use of nested brackets with *name:value* pairs. JSON had the advantage of a lightweight structure making it efficient to transfer over a data connection in comparison with XML which is verbose due to opening and closing tags. JSON fell short of our requirements because of lack of namespaces support, extensibility drawbacks and input validation [77]. The namespaces are used to provide uniquely named elements and attributes in the XML document. Once JSON was ruled out, we settled on XML and outlined the requirements for the its structure.

In version 2, the requirements extended to the other application contexts of SignSupport namely the pharmacy context and health context. To understand how the new version of XML will fit in, Figure 5.2 illustrates the contexts of use of SignSupport showing how the XML data structure and considerations fit in.

In Figure 5.2, the context of use referred to the communication domain areas or application contexts where SignSupport could be used. The ICDL context determined the scope of our research. The authoring tool organised and sequenced SASL videos and images to make them meaningful to a communication domain (see Chapter 4). XML data files, exported by the authoring tool, structured the lesson

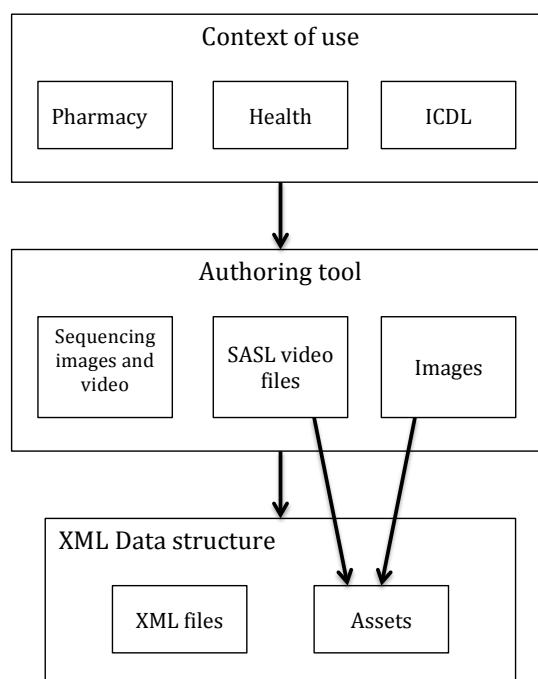


Figure 5.2: The architecture of SignSupport. The context of use highlights different communication domains and the authoring tool organises the communication depending on the context to produce the XML files and managing the assets such as videos and images

content of the e-Learner which was then parsed by an XML parser on the mobile device (not included in the Figure). Comparison of mobile XML parsers is carried out in a related SignSupport project.

Common to all application contexts of SignSupport were screens represented by a *screen* tag where SASL video instructions are viewed. These screens contained a SASL video that needed a *video* tag represent the link to the video file location. This tag was retained from XML version 1 (see Section 4.3.2). In addition, each screen had navigation buttons that allowed the user to move forward or backward between a series of screens. However, in our design discussion, navigation could not be represented in XML and was not included in the XML design.

Our application context of SignSupport differed from the other researchers in terms of user input fields. The design did not cater for user input because our

context did not utilise it but which the others needed. In the place of input, images of icons were needed for displaying together with the some of the SASL videos. These images provided visual cues to identify the icon to select which was beneficial for Deaf learners (see Section 3.1.5).

The resulting design for XML version 2 added an *image* tag. The tag contained the Universal Resource Locator (URL) of the image location represented by an absolute file path. Each *Screen* tag (see Figure 5.4) represents a screen that shows a video to the user containing a video frame and/or an image (see Figure 5.3). Figure 5.3, shows the XML tags defined to represent a lesson. Navigation tags were not defined because XML only represents data.

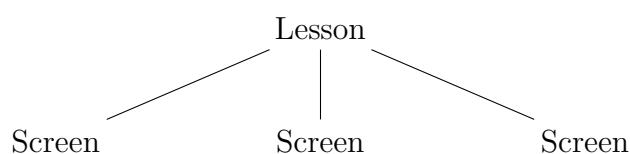


Figure 5.3: Version 2 of the XML data format showing the representation of a lesson.

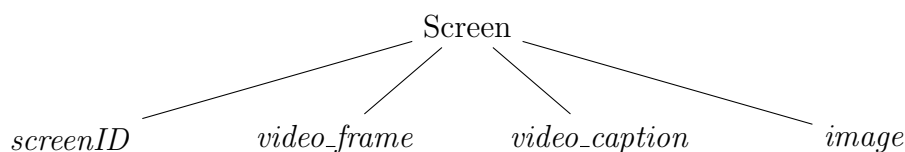


Figure 5.4: The screen element representing the data that will be displayed to the learner. The element contains child elements that will contain the necessary information for the user interface.

To avoid the user interface being cluttered, only XML elements that provided the necessary information for the learners were utilised and rendered on the user interface. These XML elements were child elements of the *Screen* tag. The *video_frame* element was rendered into a video view with media controls. The data contained in that element was the URL to the video file location. The *video_caption* text would be extracted from the SASL video file name. In addition the caption was used as an indicator to navigate the list of lesson sections shown in Figure 5.6. Navigating the list of *screen* tags was achieved using buttons built-in in the mobile prototype that traversed screen tags linearly and the rendered child elements of the screen

using the appropriate widgets in Android.

5.3.2 Mobile Prototype Design

In this section we discuss the design of the mobile prototype in terms of the user interface and the backend of the application.

User Interface (UI)

We used the previous iteration of SignSupport’s interface (see Section 2.8) design as the base for our new design. The new prototype was going to run on mobile device with a touch sensitive display. A screen activity which Deaf learners interacted with was represented in XML by the *Screen* tag (see Figure Figure 5.4). UI widgets such as the video view rendered the SASL video to the UI, the *video_caption* was viewed through a text view and the image was rendered through an image view.

The mobile phones we used to evaluate in Section 5.4.2 had a bigger screen size and higher resolution (see Table 5.1) creating more space compared with the devices used by Mothlabi. Our UI design maintained the same video frame size (640 x 720) pixels, which was similar to Mothlabi’s prototype UI design [71, p. 55]. which added additional space to the screen . The additional screen space was sufficient to insert an image view above the onscreen navigation buttons (See Figure 5.1).

Table 5.1: Comparison of technical specifications of the cell phones used in SignSupport evaluations. The third column contains display specifications of cell phones we used in our evaluation in this cycle. (Source: Samsung - <http://www.samsung.com/global/galaxys3/specifications.html>)

Specification	Samsung Galaxy S2	Samsung Galaxy S3
Screen size (inches)	4.3	4.8
Resolution (pixels)	480x800	720x1280
Pixel density (pixels per inch (ppi))	218	306

The higher resolution screen of the Samsung Galaxy S3 smartphone allowed us to store higher resolution and more intelligible SASL videos. On the other hand, the

higher resolution SASL videos need a larger storage space. The devices we developed for had 25GB (gigabytes) of internal memory, a design consideration we took when planning. This eliminated the need to transfer SASL videos over a network as for MobileASL [26]. Storing the videos offline allowed us to reduce the data cost overhead that might prevent Deaf learners using our system.

Navigating the mobile prototype interfaces is a combination of linear and hierarchical navigation. Linear navigation was achieved by using next and back buttons in the lesson detail screen activity shown in the right image of Figure 5.1. The Deaf learner press the buttons to move forward or backward through the lesson content similar in the same activity screen. Hierarchical navigation is achieved by starting from the home screen and selecting a lesson from the list of lessons (see Figure 5.5). Once a lesson is selected, the Deaf learner is presented with another list of lesson sections. The depth of the hierarchical navigation was at most two levels from the home screen.

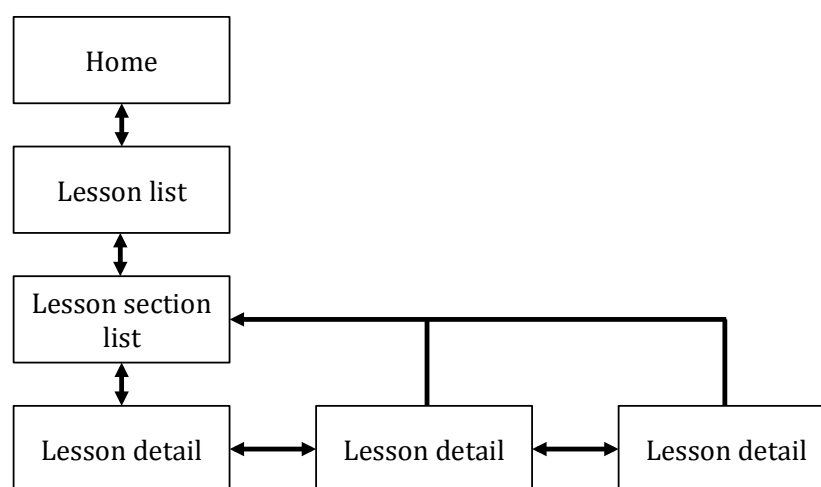


Figure 5.5: User interface navigation on the mobile prototype of SignSupport. The boxes represent the different screens the user interacts with and the arrows indicate the direction of navigation between the screens.

XML backend

We use the XML data structure described in Section 5.3.1. In the backend, XML is parsed using the Android interface *XmlPullParser* [7]. XML files are stored in the SignSupport folder are parsed and modelled using the *ArrayList* data structure in the mobile prototype. Navigation is facilitated by the use of list widgets and buttons on the interface. The list widgets display the parsed XML data and navigating through the widget was achieved using swipe gestures. Navigating through the lessons and lesson sections was achieved using a list (see Figure 5.6).



Figure 5.6: The list of lessons in a scrollable list. The learner taps on the desired list item to reveal the screen with a list of lesson sections.

5.4 Evaluate

In order to evaluate whether the mobile prototype designed could be used in a classroom, we designed a usability study to test the prototype's functionality.

The usability study aimed to test the navigability of the mobile prototype with the Deaf participants. By observing use of the prototype, it would reveal difficulties Deaf learners might face. This would be important to uncover design flaws or any interesting uses of the prototype.

We conducted the first evaluation at the Deaf Community of Cape Town (DCCT) Heathfield premises in May 2014. The session was conducted in the computer lab where the e-Learner classes are held. We met in the morning during the normal working hours of DCCT.

5.4.1 Participant Selection

Five DCCT staff members volunteered to participate in the evaluation, of which two were male and three were female. Three of the Deaf participants (we will refer to them as participants henceforth) are advanced learners who have an Equalskills certificate (see Section 2.3) in addition to completing the e-Learner adult course and receiving their e-Learner certificates. The other two participants were still undertaking the e-Learner adult course. The certificates are awarded to individuals who demonstrate basic ICT skills.

5.4.2 Cell phones

Five Samsung Galaxy S3 cell phones were used in this experiment. The device has 4.8 inch Super AMOLED display with a resolution of 1280x720 pixels. The device has 25GB internal memory with an MicroSD slot to expand memory. It runs Android OS 4.3 (Jelly bean) [4]. For this evaluation, all the cell phones were locked on portrait orientation. All participants used the cell phones in a portrait orientation at a distance suitable to each individual.

5.4.3 e-Learner lessons chosen

The lessons chosen for the evaluation were: ‘O4 - Special Keys’ and ‘E6 - Files and media’. The former was simpler than the latter. We had earlier recorded the SASL videos for these two lessons in the SCLTSL project (see Section 4.3.1).

The first lesson on Special keys required the participants to identify special keys such as the space bar, shift key and the arrow keys, on the keyboard and determine their function by looking at the graphic provided on the template. Once the learners identify the graphic that represents the action the special key performs, they drag the graphic to the row next to the image of the special key until all keys have been correctly identified. Once the learners have all finished performing the tasks above, they write their names in the text box provided on the template before printing (see Figure 5.7). The template was provided by the e-Learner software that was loaded on the computers they were using during their classes (see Chapter 3).

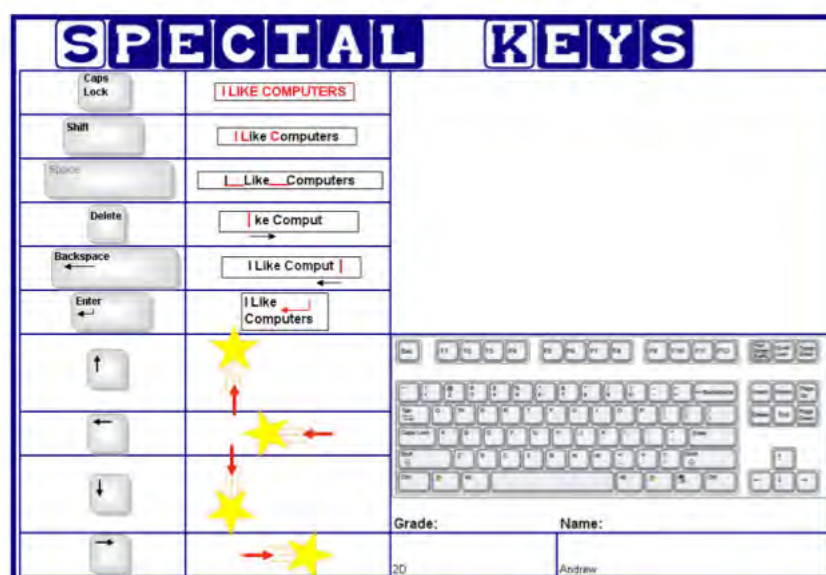


Figure 5.7: The diagram illustrating the final output of the lesson special keys once all the tasks have been completed by the Deaf learners. [2]

The second lesson required the participants to first identify storage media devices then identify images of files with their file sizes. By comparing the file size to the storage medium size, the participants cut and paste the image of the file into the column of the storage media while checking that the file size does not exceed the storage medium's capacity. The template provided by the e-Learner software is a Microsoft Excel workbook with two spreadsheets. The first spreadsheet contains the storage media in table columns illustrated by images of the storage media and their respective sizes in megabytes (MB) and gigabytes (GB). Below these is a row

highlighted in red. Each cell in this row has a drop down arrow that allows the learner to choose the name of the storage media. The cell colour changes to white and filled in with the name of the medium when the correct storage media is chosen. In the second spreadsheet, there are images of icons of different files with their names and file sizes. The learners are instructed to cut the icon, navigate to the first spreadsheet and paste the image of the icon in the appropriate column. The complete template of the lesson is shown in Figure 5.8.

Storage Size				
500GB	4.7GB	16GB	700MB	1 TB
Hard Drive	DVD	USB Flash Drive	CD	External Hard Drive
 game_setup.exe 11.28MB tonight_on_tv.html 18KB my_website.html 18KB budget.xls 1.73MB school_group.zip 892KB advert.doc 5.81MB camp_video.avi 352.673KB sunsets.ppt 4.98MB accounts.xls 3.137MB logo.gif 297KB software_setup.exe 17.75MB	 library_roster.zip 23KB poster.bmp 984KB colours.bmp 3.97KB schedule.html 324KB results.zip 492KB butterflies.ppt 3.82KB	 short_story.doc 1.82MB competition.pdf 3.80MB brochure.doc 7.52MB entry_form.pdf 1.51MB	 sandy.jpg 729KB bambi.avi 75.97MB happy.gif 174KB marketing.ppt 2.49MB wedding1.jpg 3149KB wedding2.jpg 214KB wedding3.jpg 884KB	 my_music.mp3 8.24MB passwords.txt 5KB dvd_instructions.pdf 7.84KB hip_hop.mp3 7.28MB top_ten.mp3 8.42MB bank_account.txt 2KB moms_party.mov 9.98MB shrek.avi 723.59MB details.txt 11KB birthday.mov 13.24MB concert.mov 15.827MB expenses.xls 2.82MB

Figure 5.8: The diagram illustrating the final output of the lesson files and media once all the tasks have been completed by the deaf learners.

5.4.4 Questionnaires versus Focus group discussion

In this evaluation, we purposely chose not to use questionnaires to elicit feedback from the participants. The reason for this decision was that the participants we had were functionally text illiterate and would not be able to read and answer the questionnaire independently. Motlhabi [71], noted that use of questionnaires

in an evaluation with Deaf text illiterate participants was a problem. The two SASL interpreters available to interpret his questionnaire questions for the eight Deaf participants caused a bottleneck as some participants had to wait for the interpreters to finish helping other participants. In addition, to employ more SASL interpreters was not feasible because of how rare and expensive they are in South Africa.

To solve this problem, we chose to gather information in a group discussion setting similar to a focus group where all the participants answer the same question at the same time.

5.4.5 Procedure

We observed the participants interacting with the mobile prototype and then asked about their experience. Each participant was given a Samsung Galaxy S3 smartphone loaded with the prototype and sat in front of a desktop computer that was loaded with the e-Learner Adult 1.3 software running on Microsoft Windows 7 operating software and Microsoft Office 2007.

Our team consisted of a facilitator who gave instructions to the participants in SASL and an assistant who video recorded the session while the researcher took notes. The seating arrangement placed the participants in front of a computer in a U-shaped configuration similar to Section 3.1.4. The facilitator stands in the front in a clear line of sight to give the participants instructions.

Before the evaluation commenced, all the participants were informed about the project aims and objectives and were offered a chance not to participate in the evaluation. The session was conducted in four parts:

1. The first part involved the participants being trained on how to use the mobile prototype.
2. Secondly, the participants were given a practice lesson (O4 - Special Keys) to do for 20 minutes where they would receive as much help as needed from the facilitator. This allowed the participants to familiarize themselves with the system.

3. Thirdly, the participants do another lesson (E6 - Files and Media) for 30 minutes where the facilitator gave little help to the participants.
4. Lastly, the participants were invited to participate in a focus group to give their feedback on the system.

5.4.6 Results

In this section we review the outcomes of our evaluation in terms of our aims.

Reduction of representational states

The representational states identified in Section 3.2 were reduced by four steps. It eliminated the facilitator, flip chart, data projector and assistant states. The reduced states move the Deaf participants closer to hearing literate users.

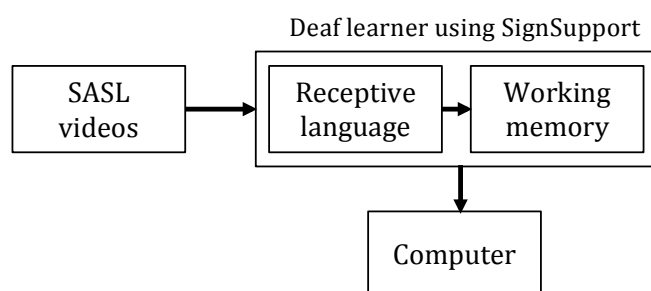


Figure 5.9: The representational states of a single instruction being delivered to a Deaf learner using SignSupport. The reduced states make it simpler for Deaf learners and promotes individual work

Navigation of the mobile prototype interface

We identified a back button navigation issue that resulted from the greyed out back button on the screen in Figure 5.10. The greyed out button was on the first lesson detail screen which indicated the first screen with signed video instruction labelled ‘*Introduction 1*’ in the list of screens. The button only became active when a user navigates to the next lesson detail screen. To navigate back to the list of lesson sections, the participants used the Android device back button which

confused three participants. One participant frantically pressed the greyed out back button in an attempt to return to the lesson sections list screen, even after training the participants how to use the system. Another participant was pressing on the top left corner of the action bar where there was no back button. Once all participants got to the screen with the SASL videos, it was straightforward for them to navigate through the content using the back and next buttons on the screen.

The training given to the participants at the beginning simplified re-watching the SASL videos. All the participants managed to tap on the video frame to bring up the video controls and replay the video. In addition, navigation between the list of lessons section screen and the lesson detail screens containing the signed videos was straightforward.

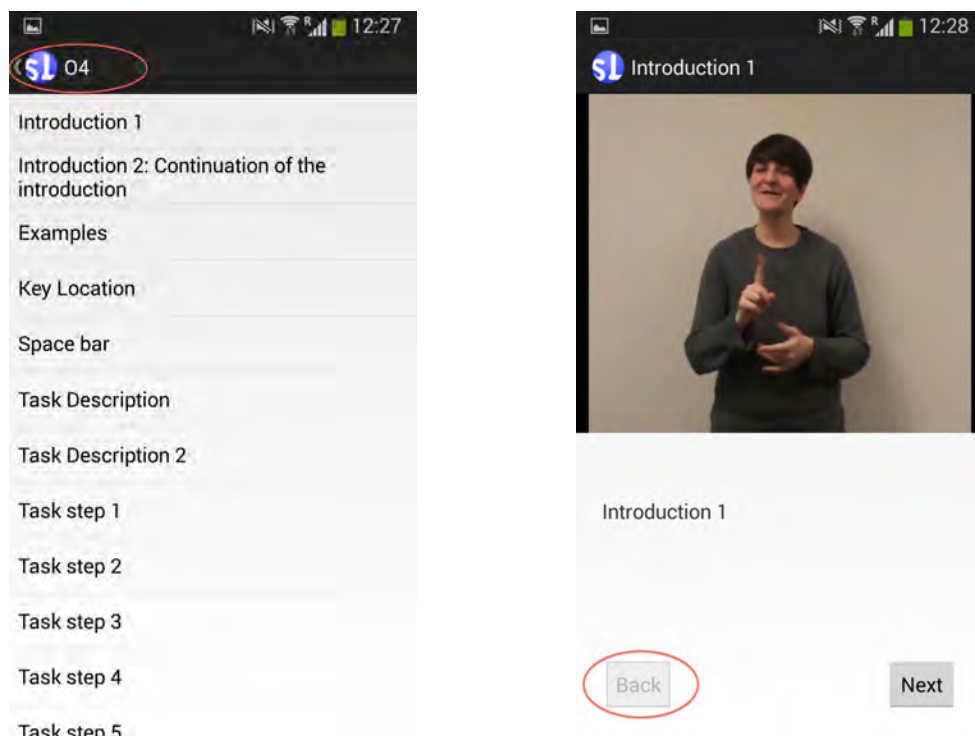


Figure 5.10: The screenshots of the lesson section list on the left and the lesson detail on the right. The two different positions of the back buttons on the screens are identified by the red ellipse around the button. The disabled back button on the right screenshot is in a light grey faded-like colour and indicates that this is the beginning of the list and will not navigate back to the lesson section screen on the left.

Lesson content

We identified issues and benefits concerning lesson content: Issue of lesson content abstraction, mismatch of instructions and use of images. We discuss them below.

1. Issue of abstraction

This issue was a result of abstracting the English text instructions in the e-Learner manual to SASL video instructions. The abstraction skipped additional supporting instructions such as discourse markers¹ [40] (a phrase or word that connects a sentence to what comes before or after) are needed to provide cues and direct the participant to perform an action such as.

In our findings on abstraction, one participant identified an instruction in a SASL video which was not clear enough to instruct them to proceed to the computer to perform a task. The participant made the correct deduction that the instruction requested them to perform the task on the computer. In other instances observed, two participants were confused between sequences of SASL videos that provided explanations and sequences of SASL videos that instructed the participant to perform a task. The participants mentioned there was no clear request for them to perform a task. One of the two mentioned that the instruction should say, “*do something and then continue*” for instructions that needed to be repeated. Another participant mentioned that one SASL video instruction that was marked as introduction yet the instruction was one sentence. The instruction did not provide a cue that the introduction continued in the next video. The same participant mentioned that in sign language, the sign for “finish” is used to indicate completion and ready to move to the next step. These instructions lacked discourse markers.

Other examples of abstraction issues were found when the participants were completing the lesson “E6: Files and Media”. One participant pointed out that the descriptions and explanations of bytes (B), kilobytes (KB) and gigabytes

¹Examples of discourse markers from [40], ‘I think this is correct. *So*, I will perform it this way.’ The italicized word ‘*so*’ is a discourse marker.

(GB) at the beginning of the lesson was insufficient. The instructions only described to the participant what the B, KB and GB were in relation to each other.

2. Issue of instruction mismatch

Instruction mismatch issues were identified where the SASL instruction asked the participant to perform a task and the participant received a different response from the computer other than what was expected from the SASL video instructions. Instruction that did not form part of the lesson content caused the mismatch. We identified five instances of this issue.

In one example, all participants identified a missing instruction that allowed them to unlock the monthly password protected e-Learner software. Lack of this instruction left participants staring at the pop-up window on their screens where they had to input the password. A workaround to the mismatch, participants raised their hands to gain the attention of the facilitator to ask for the password that was written on the whiteboard in the classroom during the evaluation.

3. Use of images

Images linked with the corresponding SASL video provided a visual guide for what icon the participants were to search for. Participants pointed out that it was easier to relate the image to what they needed to search for on their computers justifying their inclusion in the lesson content.

Issues related to signs used in SASL videos

Dialectal differences between the signs used in the SASL videos and the participants signing. All the participants identified that some signs used in the videos were different from theirs. Three participants identified the sign for ‘*size*’ in one video was exaggerated. Another participant identified the signs used for ‘*hard drive*’ and ‘*orientation*’ were signed as drive and facilitator respectively and a different sign for ‘*laptop*’ was used. The same three participants acknowledged that they clearly understood what the signs were trying to explain but the use of the different signs

bothered them. One participant mentioned that some of the signs used were confusing. We observed one participant choosing the wrong lesson because the SASL video gave them the wrong instruction. The section of instruction was signed, as ‘O1: Special keys’ instead of ‘O4: Special keys’. Two other participants identified the error in the signing in the same instruction and corrected themselves remembering that they had encountered the lesson before. These difference in signs indicated dialectal issues.

Issues related to SASL video recording

The participants mentioned that the position of the interpreter was not consistent. In some of the videos, the interpreter was standing slightly to the right of the video frame. In addition, two of the participants mentioned that the hairstyle of the interpreter was interfering with the signing. The interpreter in the video had a fringe that hid her eyebrows, important for signing questions in SASL.

Shifts of attention

Shifts of attention are actions that diverted the attention of a participant from completing the task at hand. We observed 11 instances where participants shifted their attention. One participant spent long periods watching the SASL videos on the lesson rather than performing the tasks in the lesson. Two participants stared at other participants while they were working on their lesson as a result of not understanding signs (See section on issues related to signs used in SASL videos). These shifts diverted the attention of the two participants from their own work to observe the others if they were doing the correct thing.

Handling of the mobile phone

We observed four different ways the participants were handling the mobile phones. These observations were crucial to determine whether the button placement and size on the interface were adequate. Two participants held the mobile phones in the palms of their left hands and used the right index finger to touch the screen. Two

participants put the mobile phones flat on the table and used their index fingers on either hand to interact with the touch screen.

Participant collaboration

Participant collaboration in our evaluation came about where participants assisted or referred to each other in the task completion. This came about as a result of signs used in the SASL videos being not clear enough for the weaker participants.

We observed four participants assist each other in 18 instances. In two instances, one participant understood an instruction in a SASL video or knew how to do something on the mobile application, he/she helped other participants understand it by signing it to the other participants. In another instance, one participant understood what a particular instruction in the SASL video was trying to convey and explained it in SASL to the other participants by signing to them. One participant showed another participant what button to press to navigate back to the list of lesson sections. There were two instances out of the 18 where one Deaf participant showed another participant the screen of their mobile prototype to show them which button to press.

These observed instances provided us with evidence that either the lesson content abstraction or the signing in the SASL videos needed further investigation.

Teacher intervention

We observed 21 instances where the teacher helped the Deaf participants. The teacher interventions were observed in the third part of the evaluation. The participants were instructed to do a lesson where minimal help was given to them. Two of the 21 instances observed were initiated by the participant (see Table 5.2) while the teacher initiated the other 19. Out of the same 21 instances, 9 of the instances were the teacher prompting the participant to continue with the task, click on a button or replay the task SASL video (see Table 5.3). The other 12 instances, the teacher explained unclear instructions to the Deaf participants in SASL.

Table 5.2: Table on instances observed of teacher intervention

Action initiator	Number of instances
Participant	2
Teacher	19
Total	21

Table 5.3: Table on instances observed of teacher intervention actions taken

Action taken	Number of instances
Prompting	9
Task explanations	12
Total	21

Outcomes from the focus group

At the end of the lesson the participants were asked to join a focus group. Most of the issues discussed in the focus group were discussed in the previous sections:

- Navigation of the mobile prototype interface
- Lesson content
- Issues to do with the signing in the SASL videos
- Issues related to SASL video recording

The Deaf participants additionally mentioned that they found the steps through the lesson content logical. They all agreed that the mobile prototype was good for Deaf people because it allowed them to work at their own pace and they could use it when the teacher was away. A participant inquired if the system had a facility for

them to ask questions. Another participant added that a section Frequently Asked Questions (FAQ) could be incorporated into the system.

A suggestion to have the application on the computer and use the number section of a keyboard to navigate the system was raised to avoid having switching back and forth between the mobile phone and the computer. Another participant mentioned that Deaf people outside DCCT do not have smartphones. The participant further explained when a Deaf person comes to DCCT, the system would be on the computer eliminating the need for a mobile phone. The teacher suggested that DCCT could own a number of smartphones that would be used as a shared resource. This would allow a Deaf person to come and borrow (similar to borrowing a book from a library) the phone and use it in the computer lab at DCCT premises.

5.4.7 Discussion

During the evaluation, we observed the different work rates of the participants. While the teacher was attending to a single participant, it did not affect the other participants' working on the lesson. The role of the teacher changed to an advisory role, different to the role played in Section 3.1.5 of signing lesson content, to clarify the SASL videos instructions that were not clear. Some participants needed more help and others needed little help. The participants that needed more help tended to be slower in completing the lesson while the ones needing little help were faster in completing the lesson. In addition, a participant excused herself from the class for a bathroom break. This did not affect the rest of the class. When the participant returned, it was easy for her to continue with the lesson where she had stopped or check where they had stopped by re-watching the SASL video instructions. In the previous teaching approach, the participant would require the facilitator to re-sign the instructions missed during their absence.

Several issues emerge from this evaluation. Some signs used in the SASL videos appeared to be problematic and discomforting for the participants. We recorded the SASL videos with a SASL interpreter from outside of the community (see Section 4.3.3). The difference in signs used indicated that there are dialectal differences or variation in SASL between different groups of people or communities. Despite the

different signs being used, the participants were still able to understand the context of the instructions and continue with the tasks. Some of the instructions lacked *discourse markers*. These markers gave the participant clues that the instructions continued or the instruction was a repetitive one. The inconsistencies of the signs used in the SASL videos would be addressed in the next cycle where re-recording verification of the videos would be done.

Additional SASL videos with contextual information needed to be recorded. This would address the mismatched instructions such as the information regarding the monthly password that the participants needed to unlock the e-Learner software, identified in the results. The home screen had one button labeled lessons. If we did not tell the Deaf participants what to do during the training, it would not be clear what action to take. An introductory SASL video providing contextual information would need to be recorded to provide contextual information.

In the usability evaluation, we found that Deaf participants could use the mobile prototype to complete lesson tasks despite some issues with the signing in the videos. It also allowed the participants to work at their own pace. We could not conclude whether the prototype had an effect on improving the learning experience until a comparison with the old way of learning was done which would have to be a pedagogical study that would take time. It would be important to improve the mobile prototype interface, verify the SASL videos and add contextual information to the lesson content in the next cycles.

5.5 Reflect

We sought to address content consumption on the mobile phone which we achieved. From the results, the mobile prototype allowed the Deaf learners to work at their own pace and learn in their preferred language SASL thereby relegating the role of the facilitator to a support role. The facilitator was no longer a content provider making learning in this environment a hybrid of a blended learning environment.

The signing in some of the SASL videos was problematic for the Deaf learners. Using the SASL videos which we had recorded for the students in the SCLTSL

project proved to be a bad idea because the interpreter we used came from outside the community and signed in a different dialect. In our discussion of the results in the section above we discovered the presence of dialects in SASL similar to other spoken languages. We did not cater for the difference in dialects. We learn from this experience to work with an interpreter who frequently works with DCCT. Consequently, it raised a question that we may have to address in the future: do we record SASL videos to suit the target communities' SASL dialect or do we record SASL videos that are applicable to all Deaf people nationally, irrespective of their dialects? To briefly explain, by targeting each specific Deaf community's dialect needs means in the future, for each Deaf community that would want this system would have custom tailored SASL videos for their dialect. As a result, there would be many sets of SASL videos recorded which might be expensive to make and update.

The extent to which the number of dialectal variation and the number of speakers representing each dialect is un-researched. However, as more contact amongst Deaf groups, exposure on television and interpreting, the variation merges. Deaf people recognize and understand the variations, where there is a lack of clarity this is quickly negotiated and resolved. It is the non-native signers who struggle with the variation i.e. SASL signers and other hearing people involved in some way in the SASL community.

Choosing a focus group discussion to get feedback rather than using questionnaire proved to be a good decision. Because of being resource constraints in terms of scarcity of SASL interpreters and the cost of hiring them, we avoided a situation which Motlhabi encountered during his evaluation with Deaf people (see Section 5.4.4).

The mobile prototype received general positive remarks but in this cycle it worked independently of the authoring tool in Chapter 4 and its XML output. In the next chapter, based on the feedback from the Deaf learners in this evaluation, we sought to modify the authoring tool and tie it in with the exported XML in the next cycle (see Chapter 6) of the mobile prototype.

Chapter 6

Cycle 3 – Second Authoring tool

6.1 Diagnose

We began this cycle by looking at the feedback of the previous cycle on the authoring tool in Chapter 4. We reviewed the design issues and features raised by the facilitator in the evaluation of the authoring tools presented in Section 4.3.1. The changes identified for this cycle were as follows:

- To update and implement the new XML data format version (XML version 2 in Section 5.3.1) to that of the mobile prototype in Chapter 5.
- To refine the implementation of the lesson preview functionality on the authoring tool.

We also reviewed the comments made on the SASL videos by the participants during the evaluation of the mobile prototype in Section 5.4. The feedback assisted us to make the necessary changes to our recording procedure of new SASL videos for the lesson. A lack of contextual SASL videos and discourse markers brought about instructional mismatches in the evaluation in Cycle 2 (see Section 5.4.6). The details shall be discussed below in Section 6.3.3.

6.2 Plan – Updates to XML and Recording Procedure

The first step in planning was to update the XML data format that the authoring tool will export to the format that was consumed by the mobile prototype in the previous cycle (see Section 5). The XML is the link between the authoring tool and the mobile prototype. The changes planned were to change the XML export functionality to match the XML version 2 (See Section 5.3.1). The changes were minor and not structural. We detail the changes below in Section 6.3.1.

Some of the features updated on the authoring tool in the SCLTSL project still needed to be tested out. A usability study with the target user would need to be conducted to assess whether the features had the desired effect.

The changes to the recording procedure focused on hiring a new interpreter, selecting a new lesson to record and verifying signs used in the SASL videos to address the issues identified in Section 5.4.7. We planned to record additional videos that served as discourse markers and provide contextual information. In addition we planned to include the facilitator and an advanced Deaf learner in the procedure to assist with the verification. Details of the procedure are found Section 6.3.3.

6.3 Act

We describe here the details of the changes we made to the authoring tool for Cycle 1. These changes were primarily made to the backend of the authoring tool which were functional changes rather than an update to the user interface.

6.3.1 XML changes

The changes we implemented to the XML structure involved the re-labelling of XML tags. We detail our changes below.

Image paths represented using the *image* tags that do not contain paths to image location were removed from the Screen tags. The video link and video captions were represented using the *video* and *vid_caption* tags respectively. The *id* attribute in

the video tag was removed.

The *course* tag which defines the course in XML has the attributes *namespace*, *course_id* and *course_title*. The *course_id* attribute is automatically generated by the authoring tool and the *course_title* is entered by the user when creating a course. Units are represented using *unit* tag with the attributes *unit_title* and *unit_id*. The structure of the course is illustrated by the diagram in Figure 6.1.

Similar to the XML version 2, lessons are still represented using *lesson* tag. The *name* and *id* attributes in XML version 2 are changed to *lesson_title* and *lesson_id* respectively. Added to the attribute list is the *lesson_type* that is populated from a drop down list. The final XML structure was as follows:

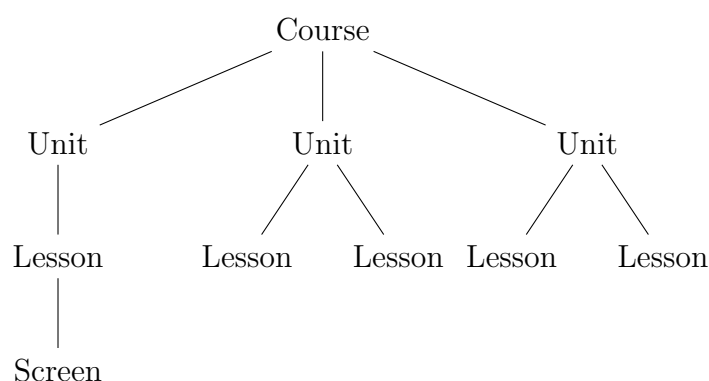


Figure 6.1: The new XML structure of the course.

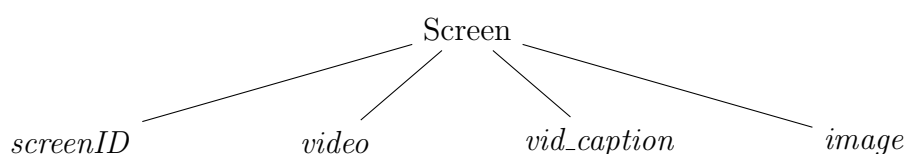


Figure 6.2: The new XML structure of the screen.

6.3.2 Changes to Lesson Preview

The facilitator identified the lesson preview needed improvement (see Section 4.4.2). We added plugins to support playback of videos encoded in using the H.264 codec. This was to avoid installation of additional plugins separate to the authoring tool. The lesson preview appears as a window on top of the main authoring tool window

with navigation buttons to move forward and backward through the authored lesson (see Figure 6.3). SASL videos included in the authored lesson were by default made to autoplay in the lesson preview window.



Figure 6.3: The lesson preview functionality of the authoring tool. The preview appears as a dialog box on top of the main authoring tool window.

6.3.3 Recording of new SASL videos

Based on the results we obtained from the evaluation of the mobile prototype and the instructional inconsistencies identified in the Diagnose phase above, we discuss our solutions here. We first had to choose a new lesson and generate a conversation script from which to sign the instructions. The procedure we followed to record the new lesson was as follows:

1. Select a lesson from the e-Learner manual.
2. Create a conversation script for the lesson.
3. Hire a SASL interpreter.
4. Record the SASL videos with the help of the SASL interpreter.
5. Edit and split the videos.

The lesson chosen was a supplementary lesson from the e-Learner manual called "S3: Our organisation" where the Deaf learners would create an organisation chart. A conversation script was generated following the similar procedure in Section 4.3.3, but tailoring the content to suit the Deaf learners. In this case, the Deaf learners will be required to create an organisation chart for their own company. In this cycle, we hired a new interpreter who had previously interpreted and worked with DCCT and was well-known by the community. This ensured that dialectal differences that were identified in the previous cycle were avoided.

Recording of the SASL videos was done at the DCCT premises during office hours. Present at the recording were the interpreter, facilitator and an advanced Deaf learner. The role of the learner was to clarify the signs used to define computer terminology used in the e-Learner classes that did not have familiar signs in SASL.

The setup of the recording was as follows: Two cameras on two tripods were used for recording. This was done to ensure redundancy in case any camera failed during the recording. The interpreter stood in-front of the camera. The facilitator and Deaf learner stood off camera watching the interpreter. In addition, off camera on a table was a laptop with Microsoft Word running.

The facilitator voiced the instructions on the conversation script to the interpreter and the Deaf learner watched the interpreter's signing to check if the signs used to define the computer terminology was correct. If the correct sign for the computer terminology was not used, the signing was re-recorded. Once the interpreter finished signing an instruction, she put her hands down. This pause in-between instructions was a marker that we used when splitting and editing the video clip. Instructions that needed more clarification in terms of the position of some Microsoft Word tools, meant that all three parties would pause recording of the instruction, refer to Microsoft word and re-record the instruction. These steps, not all, were repeated until all instructions on the conversation script were recorded. In addition to content recording we recorded short clips that were discourse markers which instructed the Deaf learner to progress forward or go back to the previous instruction.

The recording of the videos was in 1920 by 1080 pixel resolution at 25 frames per second (*fps*). After recording, the videos were edited using Adobe Premiere Pro CS

6. The captured video was first split into the shorter clips, then the audio channels were removed. To further reduce the size of the video clips, the colour channels were changed to gray scale channel in the video editing process reduced the file size [72]. The resulting video clips were short with the longest clip being 48 seconds long. The SASL video clips were renamed using the description of the instruction according to the conversation script.

6.4 Evaluate

We conducted a usability evaluation of the authoring tool at the end of November 2014 with the facilitator of the e-Learner classes.

6.4.1 Venues, Date and Participants

The evaluation was conducted in the meeting room inside the ICT4D laboratory, Computer Science building at the UCT. The facilitator of the e-Learner classes participated in the evaluation.

6.4.2 Method

We sat the participant in-front of a computer with the authoring tool running and provided a printed copy of resources names and images (see Appendix) in the order that they would appear. We instructed the participant to create a lesson using the authoring tool provided with the new SASL videos (see Section 6.3.3) and images while we watched and an assistant made notes. We encouraged the participant to speak out loud [75] her thought process which the microphone connected to the computer recorded. An assistant wrote down notes while viewing the actions of the participant via a screencast on a separate computer. The evaluation was recorded on video to capture any participant feedback after using the authoring tool.

6.4.3 Results

We report results from Cycle 3 usability testing with the facilitator here.

Interface navigation

Creating a unit was confusing for the participant. The participant was left guessing as to which unit to add the lesson to. The new unit option was hidden in the unit list drop down box as shown in Figure 6.4 where the participant had to click on the drop down list to reveal the *New unit* option to rename the new unit. Familiarity with the unit structure was easily noticed and the participant was able to relate the sections of the ‘O’, ‘E’ and ‘S’ lesson categories on the authoring tool to the lesson categories (Orientation, Essential and Supplementary) of the e-Learner in Chapter 3. The participant also identified the created lessons in their respective categories on the three list panels on the right in Figure 6.4, however it was not clear to the participant how to add the lessons to the units due to little guiding instruction provided by the authoring tool. The participant was then prompted to drag and drop the created lessons in the list panels into the placeholders on the workspace.

The participant pointed out there was no clear place to view the course or find where to modify the course. The interface was confusing and she commented, “*Where is the course? You are creating a unit but saving a course. The two mismatch.*” The confusion arose from having both the *course title* and *unit title* drop down lists on the the same screen shown in Figure 6.4. The course was only viewable as a list on the left hand side of the authoring tool (see Position A in Figure 6.4). The participant could see the unit that was being created but could not see the course being saved. Two buttons namely *save course* and *export course* (See position C in Figure 6.4) confused the participant. The participant explained that she did not understand why she had to press export course button after clicking on the save button. We explained to her that the save button saved the lesson in a format that only the authoring tool understood while the export course button created the XML ready version for the mobile prototype to consume. We pointed out to the participant that the authoring tool would be for a non-programmer.

Some navigation features of the interface did not appear clear to the participant. The button to take the participant to the interface that creates a lesson was found by trial and error. The participant clicked on a button with a *plus* icon assuming it was the correct button. Naming and creating of the lesson was not clear enough.

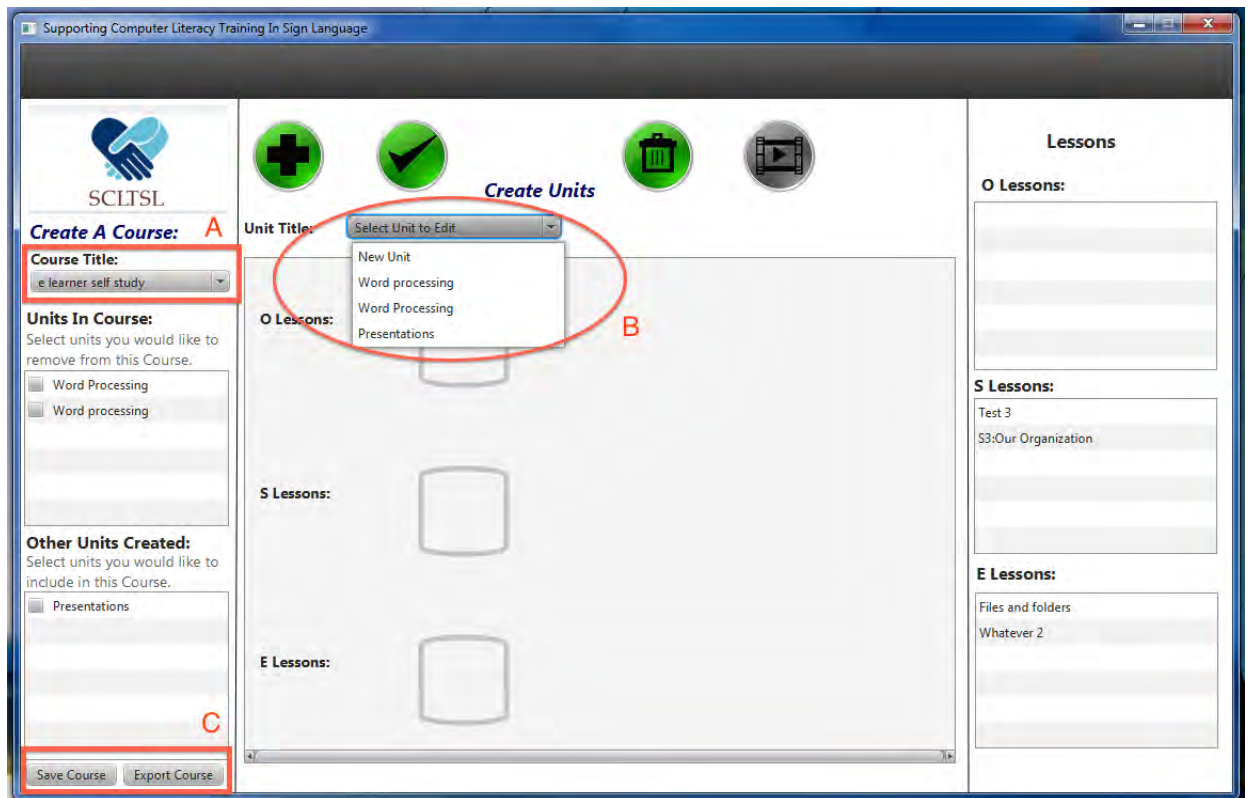


Figure 6.4: Positions of the course title (Position A), unit title drop down list (Position B) and the save and export course buttons (Position C).

The functionality was hidden in a drop down list together with pre-existing lessons shown in Figure 6.5. Choosing the category for the lesson was fairly simple for the participant who was able to locate the *Lesson Type* drop down list.

The participant spent considerable amount of time looking for the save button for the lesson. By trial and error, she clicked on the button with a tick and commented, “A tick doesn’t mean save.” The same also applied to the preview button shown in position B in Figure 6.5 where the participant made the right deduction that by clicking the button the lesson preview would appear.

Lesson creation

SASL videos recorded in Section 6.3.3 and images were used to create the lesson. These were uploaded to the authoring tool into two panels on the right (See Figure 6.5). The participant struggled with identifying the content of the video description related to the correct video. The participant suggested adding a video player to pre-

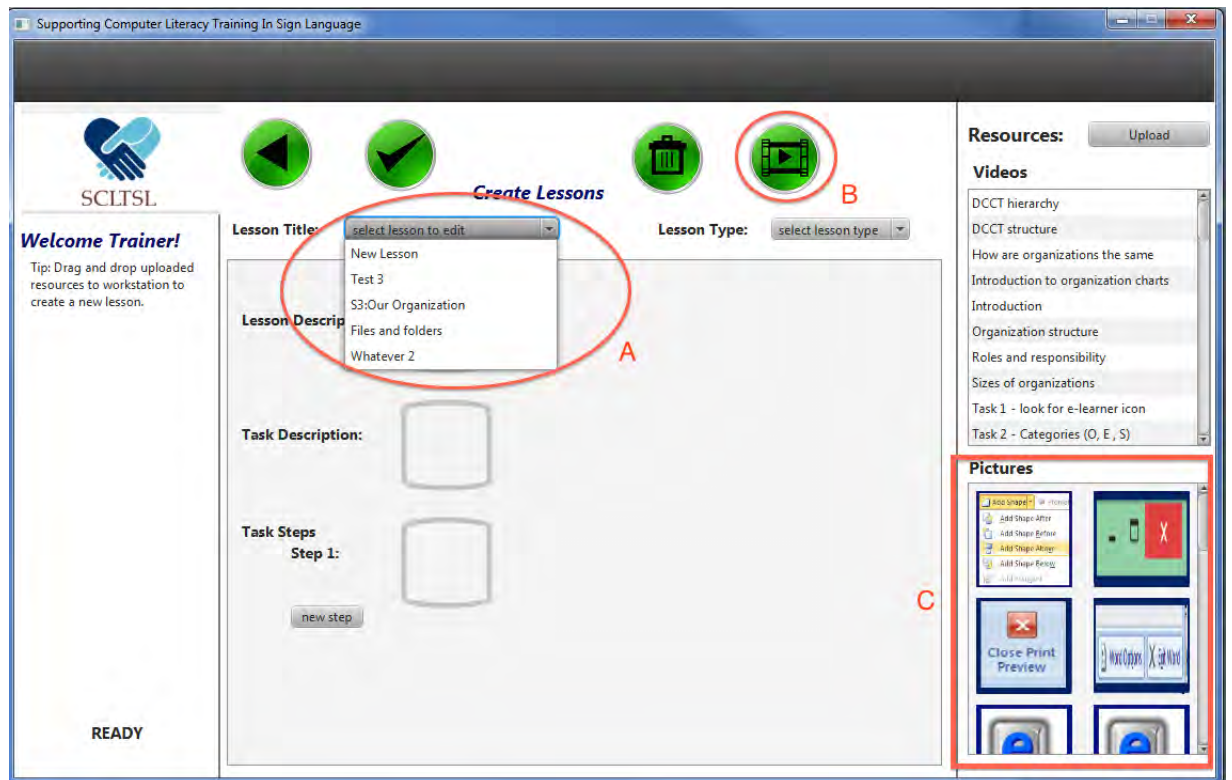


Figure 6.5: Position A of the new lesson hidden in the drop down list circled in red. Position B shows the preview button to view the lesson and position C highlighted by the red box shows the panel containing the images.

view the videos before adding them to the lesson would be helpful in the case where the videos were created by someone else. In addition, the participant expressed their frustration that the authoring tool window did not maximise and had to keep on scrolling up using the vertical scroll bar to reveal the new task step placeholder that was out of view. The images in the panel labeled C, circled in red shown in Figure 6.5 appeared small and some skewed and difficult for the participant to identify when compared with the images provided on the lesson resource list.

Dragging and dropping of lesson resources (SASL videos and images) onto the lesson canvas was seamless following the lesson resource list in the evaluation. The participant was able to drag the lesson resources into the placeholders marked by grey bordered squares in the lesson canvas where they were added to the lesson structure. We discovered a bug in the application that didn't allow the participant to remove a resource once it was placed in the wrong placeholder. This was more

an inconvenience rather than crippling the progress of adding resources. The participant got frustrated when she had to scroll up to reveal a new step placeholder once the *new step* button was pressed.

Once the participant found the preview button, the participant managed with little effort to preview the lesson using the forward and back navigation button on the preview window. The participant however commented, “*I am not sure where it starts,*” stating she was not sure where the lesson preview started. We explained that the lesson preview started from the beginning of the lesson.

6.4.4 Discussion

We discuss issues highlighted in the results above.

Hidden and Absent functionality

Some elements necessary for the creation of the lesson were hidden in drop down lists instead of making them more visible to the user. The naming of the drop down list *lesson Title* did not also provide the participant with any hints how to name the created lesson. Visibility of the functionality would have been greatly increased by having distinct buttons and adding tool-tip pop-ups when the participant hovered over the tool using the mouse.

Previewing of the videos resources prior to dragging and dropping them in the lesson canvas was not possible, although the participant wanted the feature to be there. The participant commented that it would be useful in the case that the videos were edited by a different person. This could avoid adding a video resource to the wrong position and verify if content of the video was correct.

Functionality to name created lessons, units or a course was hidden in drop down lists that resulted in trial and error attempts. Once the participant was shown how to rename the lesson, the participant made the correct deduction to check the other drop down lists for the course and unit. A suggestion from the participant was to have the unit list drop-down box pre-populated with the existing names of the 7 units in e-Learner with an “other” option to name a custom unit.

Lesson Creation

Adding lesson resources to the lesson structure was a simple drag and drop task. However, the view of the lesson was limited due to the authoring tool window not able to maximize and fill up the whole screen which made viewing the picture thumbnails difficult. In addition the window size made scrolling the pictures panel locating for the correct image cumbersome. Despite these inconveniences, the participant managed to create the lesson using the authoring tool.

A wizard to guide a first time user of the authoring tool would provide additional help to address the confusion and demonstrate the navigational features. Then with added proficiency whilst using the system, the wizard can be turned off.

6.5 Reflect

Our changes to the authoring tool were not visible to the user. The XML changes would be determined effective in the next cycle. The authoring tool did allow the facilitator to create a lesson using a predefined lesson list provided. An overlooked factor when creating the lessons was naming of the edited videos. The videos could be created by a third party and the facilitator would need to know the content of the videos before adding them to the lessons.

Visibility of key naming functions of the lesson and unit were obscure which made them frustrating to do. This could be avoided by making the functions more visible by providing the drop-down list a more suitable label or moving the naming function to a more suitable and visible position on the interface.

In Section 6.3.3 we had an advanced Deaf learner participating in the recording procedure of SASL videos. The input received from the learner helped clarify SASL terminology that was used in the classes. The quality of SASL signs used was greatly improved by hiring a SASL interpreter known to DCCT. The clarity of the SASL instructional videos would only be evaluated in the next cycle.

We made changes that would make the exported XML from the authoring tool work with the mobile prototype which its effectiveness would be investigated in the next cycle.

Chapter 7

Cycle 4 – Second mobile prototype

7.1 Diagnose

We began by reviewing the results of the mobile prototype evaluation in Cycle 2 (see Chapter 5). The concerns from the facilitator and the Deaf participants was to do with some signs used in the SASL videos which highlighted the dialectal differences.

We revisited the design of the mobile prototype and found that contextual information was lacking from some of the different screens of prototype which would help the Deaf learners navigate through the prototype. This coupled with problems with the back button navigation would be addressed below. In the previous mobile prototype cycle, we used a hand-coded XML data structure that was co-designed in Cycle 1 (see Section 4.3.2) and not generated by the authoring tool. In this cycle, the mobile prototype parsed the XML data structure generated by the authoring tool in Chapter 6.

7.2 Plan

The work to be done on the prototype was on fixing bugs and usability problems identified in the results of the previous cycle of the mobile prototype (see Section 5.4.6).

In Cycle two, we found that the mobile prototype needed contextual information that would help the Deaf learner navigate the prototype. The contextual informa-

tion were instructions to direct the learner how to access the lesson content and other instructions that did not form part of the lesson content abstraction from the e-Learner manual. To address this, we identified screens where contextual information would be placed in the form of SASL videos. The first place would be in the home screen to have a welcome SASL video to explain how to access the lesson content. The additional contextual information rectified the instructional inconsistencies that the abstraction of lesson content left out, for example, the instruction to enter the monthly password to unlock lesson templates on the e-Learner computer software which resulted to instructional mismatches (see Section 5.4.6). The videos for contextual information were recorded in Section 6.3.3 and we needed to incorporate them in the design of the prototype in this cycle.

We also had to set a date for the prototype evaluation. All Deaf learners are staff members, their work came first, making the selection of an evaluation date difficult when we could get most if not all of the learners together.

7.3 Act

We discuss the changes we made to the mobile prototype, addressing the usability problems identified Cycle 2 (Chapter 5). They are detailed in the sections below.

7.3.1 Usability solutions

Back button navigation

Two changes were made with regard to the back button navigation: Firstly the device hardware back button was disabled. Previously, the device back button navigated from the lesson detail screen to the lesson list screen (see Section 5.3.2). Instead, all back navigation was done using the left-facing arrowhead (See position A in Figure 7.1) at the top left corner of the title bar at the top of the application. To avoid confusion, the button with the label *back* is used to navigate back to the previous lesson detail screen with SASL video instructions. The Figure 7.1 below shows the new position of the back button. The second change removed the greyed out back button on the interface which confused the Deaf learners. The back button

only appeared once the learner had navigated to the next screen. Similarly, the next button was removed once the learner had reached the end of the lesson.

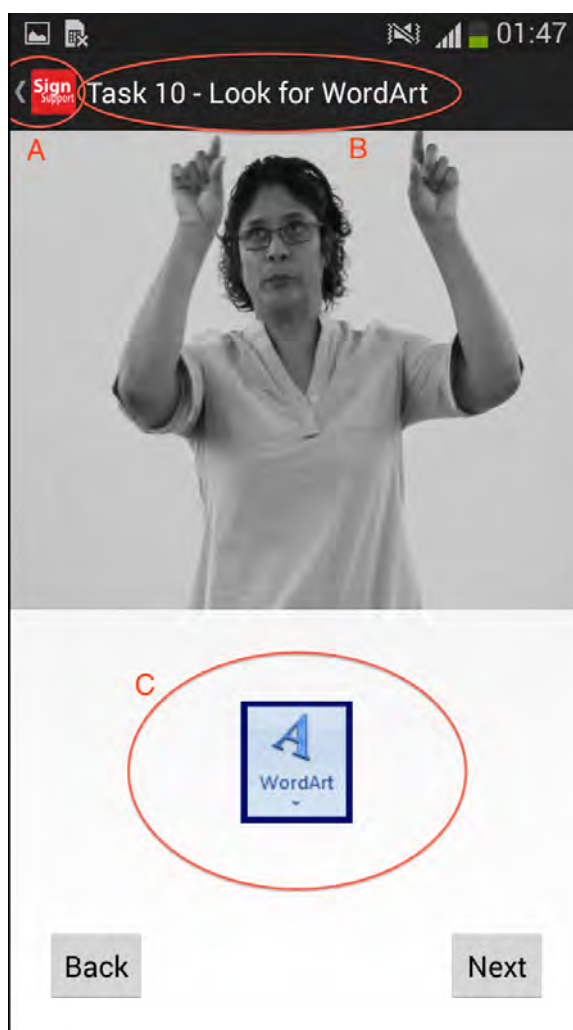


Figure 7.1: The improvements to the interface of the mobile prototype in cycle 4. Back button navigation is at the top left (position A) of the action bar indicated by the left-facing arrowhead, consistent in all screens. The video caption is at the top in the action bar (position B) and the image is now centred at the below the video frame (position C).

Video captions and image positioning

The video caption was moved to the action bar at the top of the application to become the video title (see Figure 7.1) which goes against web content guidelines (WCAG 2.0) in terms of accessibility and in-video captions [99]. The text on the video title corresponded to the text on the lesson section list item that was clicked

which was a shorthand form of the signed text in SASL video to provide a brief description of the instructions in the video. The video title allowed the learner to identify the relevant video instruction while scrolling through the list of lesson sections. As a result, more space was created at the bottom of the video frame to position the image that accompanied the video. The resulting space allowed larger images to fit in without the need to shrink the image dimensions.

Contextual information

We included SASL contextual information videos which were recorded in Section 6.3.3. In the home screen of the application, there were two buttons (lesson and exit buttons) where without further information, the learners did not know what to do. An Android video frame widget was added to the home screen that would display the SASL video that will introduce the prototype to the learner and instruct them to click on their desired button (see Figure 7.2).

7.4 Evaluate

In Cycle two we found out that the Deaf learners could use the mobile prototype to do individual learning despite the dialectal differences. In this cycle we performed usability testing to assess the effectiveness of the changes and refinements in the new recording procedure (See Section 6.3.3) and the user interface changes we implemented to address these problems identified in the diagnose phase.

7.4.1 Venue and Date

The evaluation was at held at DCCT premises in 2014 during the normal working hours of the NGO. We used the computer lab that the learners use for the e-Learner classes.

7.4.2 Participants

We had four participants in the evaluation. Three participants were in the user evaluation in Chapter 5 and one participant was new to the project. Two participants

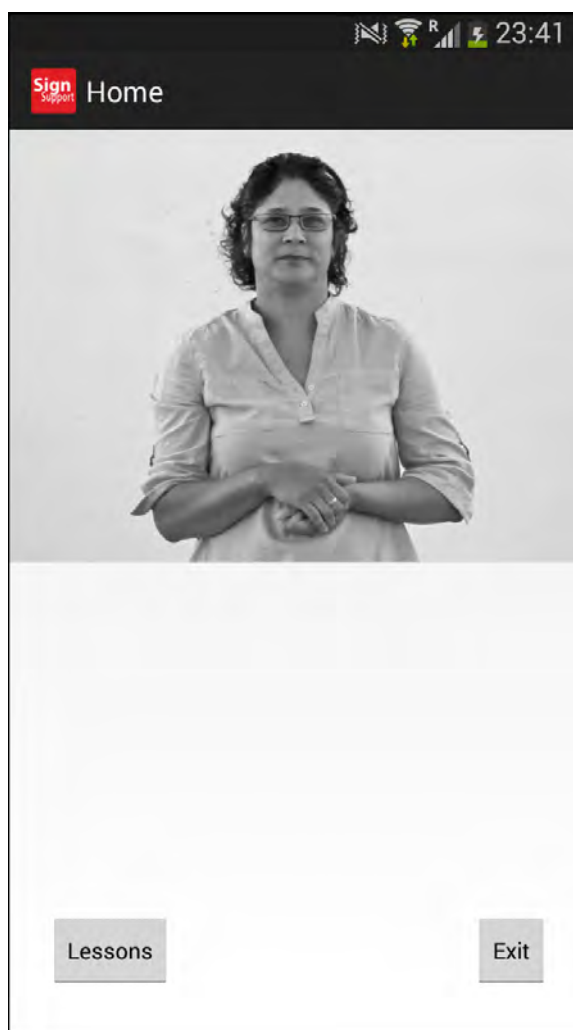


Figure 7.2: The home screen with the welcome message and contextual information in a SASL video. The video informs the Deaf learner where to find the lessons and how to exit the application.

were advanced learners, one an intermediate learner and the last one a beginner who had just began the e-Learner classes. Also present, a Deaf learner who was involved in the filming of the SASL videos (see Section 6.3.3), was assisting the facilitator in this evaluation.

7.4.3 Procedure

Similar to Cycle Two (Chapter 5), the Deaf learners sat in front of a computer and were provided with a mobile phone with the prototype, similar to the ones used in Section 5.4.2. The Deaf learners were first introduced to the project then they

proceeded to use the mobile prototype to complete a lesson following the instructions provided in SASL video on organisation charts (see Section 6.3.3). Once the session was done, the Deaf learners were invited to participate in a focus group discussion to give feedback instead of using questionnaires (see Section 5.4.4). Present in the session were ourselves, the facilitator of the e-Learner course and a researcher who assisted with video recording the session. The facilitator and assistant (Deaf learner) were only there to clarify the SASL instructions. The facilitator, in addition, interpreted on our behalf.

All instructions the learners need to perform were in the recorded SASL videos (See Section 6.3.3) accessed on the mobile prototype. The learners followed the instructions in order to create a organisation chart of DCCT. The mobile prototype would be used simultaneously with the computer where the learners would perform the tasks.

We collected data from the evaluation using notes on our observation that we took down in a notebook, photographs and a video recording of the session that would be analysed after the session. Observations and comments made by both the facilitator and the assistant Deaf learner were recorded on video for later analysis.

7.4.4 Results

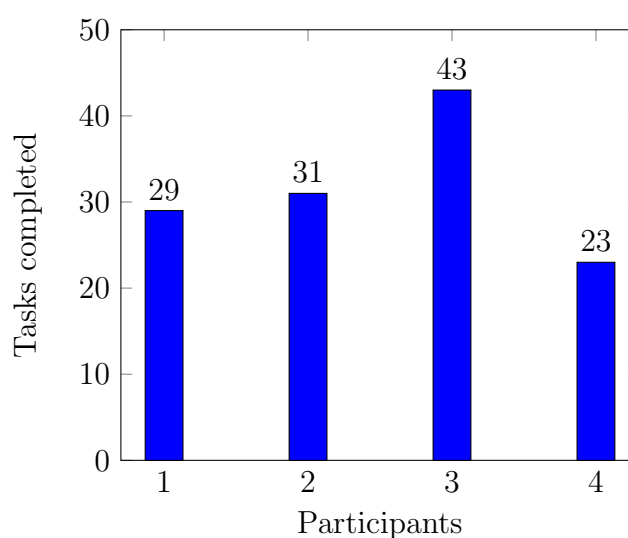
We report results from Cycle four usability testing here. We did not evaluate how the learners held the mobile phones.

Task completion

The lesson consisted a total of 51 SASL videos consisting of 7 lesson description videos, 1 video on task description and 43 task step videos. These videos correspond to the sections of the e-Learner lesson structure of lesson description, task description and task steps (See Section 3.1.3) to maintain consistency. The fastest learner completed the whole lesson in 1 hour 6 minutes. Table 7.1 below shows the tasks completed by the Deaf participants. These tasks correspond to the 43 task step videos. The chart in Figure 7.3 visually the completion rates of the tasks.

Table 7.1: Task completion rates of the lesson by the Deaf participants.

Participant	Lesson de- scription	Task description	Task steps completed	Total
1 (intermediate)	7	1	29	72.5 %
2 (advanced)	7	1	31	76.5 %
3(advanced)	7	1	43	100 %
4(beginner)	7	1	23	60.8 %

**Figure 7.3:** Chart showing the task completion rates of the participants in the user evaluation

The progress of the other learners was recorded and we printed copies of the documents the learner were working on. Figure 7.4 illustrates the complete organization chart by participant 3. Screenshots belonging to the other participants can be found in Appendix D.

Reduction of representational states

The reduction of representational states discussed in the results in Section 5.4.6 was maintained. It kept the same the number of representational states as for hearing literate users.

My Organisation

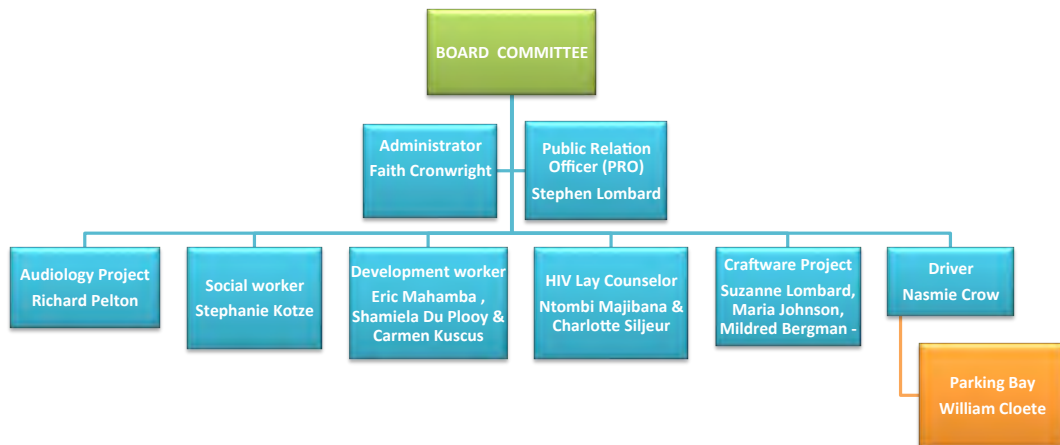


Figure 7.4: The complete organization chart. The chart shows the structure of DCCT with all jobs added completed by participant 3

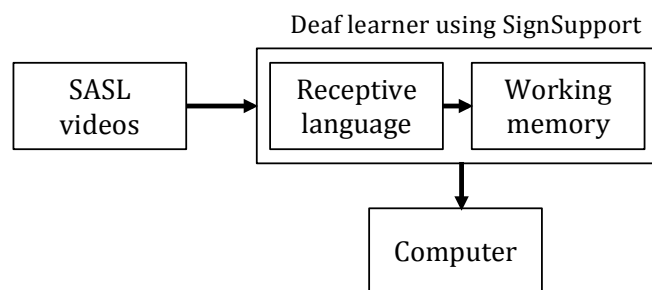


Figure 7.5: The representational states of a single instruction being delivered to a Deaf learner using SignSupport. The reduced states make it simpler for Deaf learners and promotes individual work

Interface Navigation

We fixed the navigation issues found in Section 5.4.6. We removed the disabled back button that confused the participants. All participants managed with relative ease to navigate between the lesson list screens and the SASL video screen using the using the back button on the status bar at the top left of the application.



Figure 7.6: Red circle shows the position of the back button marked by a left facing arrow head next to the SignSupport icon on the title bar. The learners press this button to go back to the lesson section list.

The participants recognized that the home screen contextual video (see Figure 7.2) was clear enough for them to follow. They followed the instructions in the video to access the lesson list screen by pressing the lessons button. Two participants (participants 2 and 4) observed did not proceed forward to the lesson detail screens where they would start the lesson. The screen they had stopped at lacked SASL instructions to tell them what to do. The participants were prompted by the facilitator to click on the introduction list item to navigate to the next screen.

Lesson content

All the participants could follow the signing in the SASL videos. There were no dialectal difference identified in the signing compared with the results in Section 5.4.6. One participant (participant 1) recognised the sign for the word *organization* but did not know the English spelling. The assistant aided this participant by typing the correct spelling in an open word document which was projected at the front of the room using the overhead data projector. In addition the same participant identified the sign for *tight* but could not relate it to the English word which required her to apply text wrapping.

Two mismatches of instructions were observed. In one instance, two participants (participant 1 and 4) pointed out that the SASL instruction required them to save the document in their local folder but their folder was not present. It was also noted that the participants were not seated at the computer they normally use for the classes. The computer normally used by participant 1 was faulty and the computer used by participant 4 was being used by an advanced learner (participant 2). The facilitator instructed them to save the documents on the computer desktop. In the other instance, one of the two participants (participant 4) noted that there were three e-Learner icons on their computers while the instruction on SignSupport instructed them to click on the e-Learner icon. The advanced learner clicked on one of the e-Learner icons which opened the application. The novice learner (participant 4) sought help from the facilitator on which icon to choose to open.

Learner work rates

We observed that the novice learner (participant 4) needed more help compared with the other 3 learners. In the instances observed, the novice learner needed prompting to carry on. In one instance the same learner (participant 4) was staring at a dialog box on her screen where she had to click the *Ok* button for the dialog to disappear. In another instance the learner called the facilitator to confirm where the SmartArt object chosen was the correct one. From our observation, the difference in computer literacy between the advanced learners and novice learners was evident. This allowed the assistant or facilitator to assist the novice learner more while the advance learners

(participants 2 and 3) continued with their individual work uninterrupted.

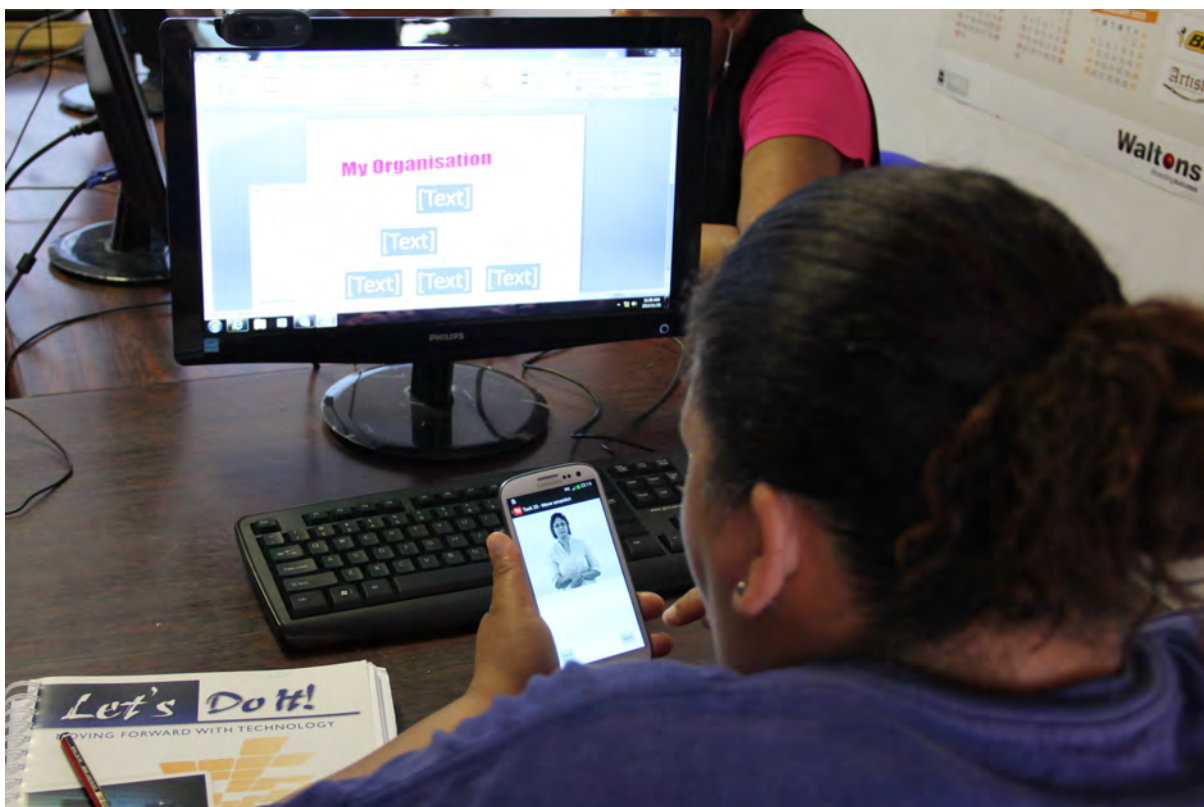


Figure 7.7: A Deaf participant using SignSupport to do the lesson, *S3: My organization*

Facilitator engagement

The facilitator engaged with the Deaf participants in 25 observed instances. The engagement involved clarifying potentially confusing instructions or to prompt the learners. In one instance observed the facilitator explained to an advanced learner that the 3D effect to be added was for *WordArt* instead of *SmartArt*. The facilitator also instructed the assistant to help with problematic spelling, for example the word organization.

Assistant engagement

The assistant engaged with the Deaf participants in 28 instances observed. In these engagements, the assistant prompted the Deaf participants to clarify some of the SASL instructions that the participants misinterpreted. In the event that the assistant was not sure of an instruction, the facilitator was consulted.

Outcomes from the focus group

In the group discussion, all the participants had mixed reactions towards the prototype. One participant (participant 4) mentioned they had difficulty choosing a lesson. The same participant, who was the novice learner also did not know the hierarchy of DCCT. Another participant (participant 1) had difficulty with relating the signs to the English word. Three of the participants (participants 1, 2 and 4) were satisfied having the assistant helping them when the facilitator will not be present. Participant 3 who finished the lesson was satisfied that SignSupport allowed her to work at her own pace.

All participants were satisfied with having the image beneath the SASL video however participant 3 wanted the image size increased to fill up the space. The participants would like all the lessons filmed, but they all indicated they would still need help from the facilitator. All the participants agreed that Deaf people outside DCCT could use SignSupport with sufficient training.

7.4.5 Discussion of results

In this evaluation we had a diverse group of participants in terms of their computer literacy. Three of the participants (2 advanced and one intermediate learner) use computers as part of their work. The novice learner does not use a computer and began the e-Learner classes at the beginning of the year. The learner therefore needed more help from the assistant and facilitator. It also revealed the different work rates of the participants. From the results, the advanced learners showed more individual work progress compared with the novice learner.

The instruction mismatch identified where the participants folder was not present on the computer could be addressed by adding a SASL video. The video will instruct them to create a folder if they do not have one and save their work there. By doing this, the participants would not have to be bound to the computer they work on. Using the authoring tool in Chapter 6, adding the SASL video to the existing lesson structure would be made easy.

The reduced representational states of information removed the facilitator from

being the content provider and other states that were used to deliver instructions to the Deaf participant. The SASL video instructions state in Figure 5.9 replaced four states identified in Section 3.2 and make representational states similar to a hearing literate learner shown in Figure 7.8 below.

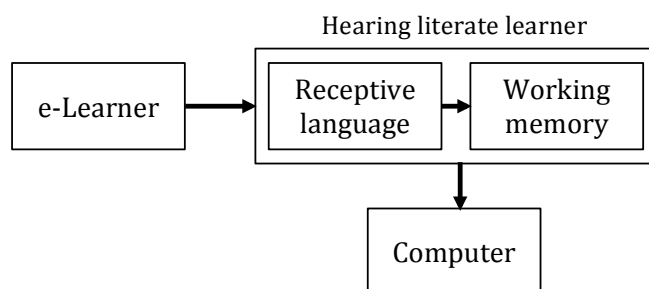


Figure 7.8: The representational states for a hearing literate person. The boxes show the different representational states for the different media.

The signing in the videos was clear to the learners and dialect differences did not emerge because we hired a SASL interpreter known to the participants (see Section 6.3.3). One participant had difficulty relating the SASL sign to the English terminology. The addition of the SASL videos that are discourse markers provided the participants with clues that the instructions were repetitive or continued to the next SASL video.

Addition of the contextual information videos reduced the instruction mismatches where the participants had to enter the monthly password. The other contextual SASL video was on the home screen providing information of how to proceed to the lessons. Two additional contextual videos would need to be added to the screen where the learner chooses a lesson. The other video would be put in the lesson section screen. The lack of the contextual video in the lesson section screen caused two participants from progressing to the lesson detail screen.

Having the assistant, a Deaf person, present proved to be helpful in reducing the workload of the facilitator. The assistant helped the participants with terminologies and unfamiliar signs in the case of new terminology that was developed in the class. The reduction in workload is shown by the 25 observed instances of facilitator engagement compared to the 28 instances observed of the assistant. In addition,

this allowed the facilitator to take a step back and allow the assistant to run the session demonstrating signs of sustainability of SignSupport. If all the lessons were recorded, the assistant would be able to work without the need of a teacher. The only requirement is that the assistant would have to be well versed with lesson material.

The classroom environment observed in the evaluation became a blended learning environment. The lesson content provided electronically by SignSupport and the assistant and facilitator being present to assist in person. It would allow the facilitator more time to engage with the learners and assistant rather than deliver content.

7.5 Reflect

Looking at the results, we had to reconsider who our target group is for SignSupport. The novice learner required help in numerous observed instances compared with the advanced learners with exposure to computer literacy demonstrated by the work rates of the advanced learners. SignSupport looks best suited for Deaf learners with some basic computer literacy exposure to allow them to do distance learning. Currently, SignSupport is effective in a blended learning environment.

The interpreter chosen to record the SASL videos helped us use the signs familiar to the participants. In addition having a Deaf learner present at the recording session helped clarify new terminology developed in the e-Learner classes. The participants in the evaluation pointed out that the signing was clear to them.

Introduction of the assistant, a DCCT staff member, was a good decision to guarantee the success of SignSupport. This would allow the facilitator role to be transferred to DCCT staff members once they become proficient in computer literacy skills. After that the staff members can pass on the skills to the rest of the community. The facilitator would still be relevant to help develop and correct the Deaf learners' English vocabulary and help link signs to the equivalent English terminology.

SignSupport in this cycle received positive remarks and worked with the lesson

content created by the authoring tool in Chapter 6. We have demonstrated that it allowed Deaf learners to work individually at their own pace and reducing the workload of the facilitator. Furthermore, SignSupport has shown signs of being a sustainable solution to support computer literacy training.

Chapter 8

Conclusion

We conclude by drawing together reflections from each of our cycles regarding to our research questions and method, reflecting on action research, summarising the contributions of our work and discussing future work. We sought out to answer our two research questions in the following sections.

8.1 Reduction of dependency on teachers

The first research question we investigated (see Section 1.6) was:

1. What are the potential ways a mobile phone can reduce dependency on teachers?

In the study, we revealed intermediated supported learning mentioned in our research theme (Section 1.5.2) where learning was through an intermediary, the facilitator. Our field study and classroom participation uncovered the difficulties that Deaf learners encounter. We identified that a challenge was to provide lesson content to Deaf learners in SASL. This resulted in a dependence on the facilitator for lesson content delivery. Since the Deaf learners had very low English literacy the written English text in the e-Learner manual had to be interpreted into SASL for the Deaf learners to understand, increasing the cognitive overhead for the facilitator. Since the Deaf learners were experienced users of mobile phones, the mobile phones had the capacity to support multimedia supported learning.

We also traced the evolution of the above research question. In Cycle 1 (see Sec-

tion 4.1), we identified that the authoring content depended on a programmer which caused a bottleneck in content creation. Our expanded question, within our theme, addressed two scopes of dependence: facilitator dependence on programmers and Deaf learner dependence on facilitator. We addressed the first scope of dependence with the introduction of the authoring tool. The second scope was addressed by the use of a multimedia learning system appropriated for mobile phones since Deaf users were experienced users of mobile phones.

8.1.1 Control over Content

The difference between our system and the previous teaching method is that we have eliminated the need for the facilitator to translate written text, exhibiting multimedia supported learning. Our system provided access to lesson content in SASL videos, easily available on mobile devices and can be carried home. SASL lesson videos can be recorded once and authored by the facilitator using the authoring tool.

The authoring tool gave the facilitator the capacity to create lessons tailored to the Deaf learners, as a domain specialist. Although the authoring tool being an initial prototype, it served the purpose of reducing the facilitator's dependence on a computer programmer to create the content. The benefits were that the quality lesson content was not influenced by her signing ability and spending double the time interpreting.

Content creation was more than simply translating the e-Learner lessons. Contextual information and discourse markers – instructions not part of the e-Learner manual – needed to be recorded. This ensured that the lesson content was navigable and reduced chances of instructional mismatch. The only limitation of the content was the lengthy duration of translating and recording of new lesson content. Despite this limitation, the recording is done once since the e-Learner course rarely changes.

8.1.2 Facilitator workload and dependence

Our system reduced the facilitator's workload which was, at most times, delivering content. The role of the facilitator changed into a support role to clarify unclear SASL instructions to slower weaker learners. The decrease in representational states caused a reduction in cognitive overload for the facilitator. The need to interpret the lesson material was eliminated. In addition, results from Section 7.4.4 indicated introduction of a Deaf assistant (an advanced learner) allowed the facilitator to step back and allow the Deaf community facilitate the lesson which would be beneficial for the sustainability of the classes.

8.1.3 Benefits to DCCT

Before our system, Deaf learners could only have classes subject to the facilitator's availability and schedule (see Section 3.1.1). In Cycle Four, we introduced the assistant (see Section 7.4.4) who showed potential to conduct the classes with our system providing the instruction. The system demonstrated aspects of sustainability having the community take ownership of the artefact.

8.2 Promotion of individual learner work rates

The second research question we investigated was:

2. How effective are mobile phones in supporting computer literacy training?

For the most part results discussed here were obtained in Cycles 2 and documented in Section 5.4.6. We found that the mobile prototype simultaneously with the computer allowed Deaf learners to learn at their own pace which consequently reduced the workload on the facilitator. The need to translate written text from the e-Learner manual reduced the cognitive overload for the facilitator. We see the system supporting multimedia supported learning allowing the Deaf learners to complete tasks reinforcing our theme: *Support*.

Since SignSupport was mobile based and Deaf learners were experienced mobile users, to have a desktop version (as suggested by a Deaf learner in Section 5.4.6)

was a challenge to address. The Deaf learner needed to have some basic level of computer literacy to access the computer and use that desktop version. Instead, the mobile version was more viable option given the level of computer literacy of the learners.

8.2.1 Benefits for Deaf learners

The Deaf learners benefited from having lesson content in their first language, SASL. The learners had a chance to review/revise the videos of the recorded lessons at their own time. The facilitator, whose role changed from content disseminator to mentor/adviser, was readily available to answer any learner queries.

8.2.2 Facilitation of Blended learning

Our system facilitated the emergence of a blended learning environment. Instructions were delivered electronically via the mobile prototype and the facilitator and assistant were present to assist the Deaf learners. The emergence of blended learning reinforced our theme of support whereby multimedia supported learning was achieved.

We also observed in the results of Cycle 2 (see Section 5.4.6) collaboration between the Deaf learners which. The collaboration did not affect the individual pace of the class which was a feature of blended learning.

8.3 Reflection on methods

We reflect on each of our methods used in this project.

8.3.1 Community-based Co-design (CBCD)

CBCD allowed us to immerse ourselves in Deaf culture at DCCT. Our weekly, sometimes more, visits to DCCT facilitated developing a long term relationship with the community. We participated in DCCT events, for example Men's workshop, and pro-bono skill based volunteering gave us a overall view of the impact of DCCT on

the larger Deaf community. In return, DCCT staff members assisted us in our research reinforcing the ethics of reciprocity.

The design agenda was driven by the Deaf community. Despite them being inexperienced in design, they were experts in their communication domain, their perspective and input were valuable in driving the design of the system. The cycles of research allowed us to produce tangible results which the Deaf community could actually see and relate to.

Collaboration brought together a multidisciplinary team that each brought in a different perspective to the project. The Deaf community steering the design process as experts knowing their problems, the Deaf education specialist – the facilitator – providing us with insight into the Deaf community’s practices and educational background and us the computer scientist implementing the solution.

8.3.2 Usability Evaluations

We gathered a number of insights about our system interfaces from a small number of users, being conducted in the same conditions the users would be learning. They allowed us to gain insight that informed the design and other insights on the Deaf learners learning individual work rates. The usability studies brought about emergence blended learning.

It was important that the process did not take longer than the duration for the classes. To that end we ensured that the session did not exceed the allocated duration (See Cycle 2 and Cycle 4). Both sessions were video recorded and further explained in Section 8.3.4.

In all cases of usability evaluations, the number of Deaf learners (see Section 3.1.2) we had access to limited us. The evaluations were qualitative in nature because they were too few to provide a statistical significance.

8.3.3 Field study

In Chapter 3, the e-Learner classes helped us gather data on the intricacies and difficulty that Deaf learners encounter while learning new skills as well as gather

data on the existing technology capacity. It also helped us understand the cognitive overload that the facilitator endures while translating text into SASL. These results were published in [74]. Other methods of data capture via direct observations, note taking, interviews provided qualitative data on the learning environment.

8.3.4 Video recording

Video recording and analysis assisted us in identifying things that we would have not identified. Analysing the video content provided us with valuable data on the number of instances of assistance between the Deaf learners with the facilitator and the assistant, which allowed us to see if our system did reduce the workload on the facilitator.

In addition, video recording of lesson content provided us with valuable insight in ethics of dealing with scarce and time constrained SASL interpreters. We also found out that it was necessary to have one of the Deaf learners present during the recording process. Their role proved valuable in verifying the correctness of the signs used in the recording. We have provide a guidelines for authoring in Appendix G.

8.3.5 Interviews

The interviews in the form of conversations with the facilitator after the classes. These provided qualitative data to support our direct observations in the field study. Data gathered provided insight into the DCCT culture and their projects that the computer literacy skills could benefit staff members. As an informant, the facilitator acted as our gatekeeper to the Deaf learners.

8.3.6 Focus Groups

Focus groups allowed us to gather data quickly about the system after usability evaluations in Cycle Two and Four. This was more effective than using questionnaires which were found to be difficult to use (see Section 5.4.4) which also helped cutting costs of hiring additional interpreters.

8.4 Action Research

In our discussion of Action Research (see Section 1.4) we mentioned three important characteristics of AR: they triangulate multiple methods, they are cyclical and they prioritize user input. We discuss them below.

8.4.1 Benefits of Iteration

Iteration provided several benefits:

- It allowed for continuous feedback to the Deaf learners and facilitator.
- User interfaces were improved by addressing difficulties that users experienced in earlier evaluation.
- We could reflect on our methods to better suit the context, for instance moving from generic e-Learner lesson tasks for usability testing in Cycle 2 to tailored lesson tasks for the Deaf learners in Cycle Four (see Section 7.4).

8.4.2 Prioritising Participant Input

The entire research project rested on the efforts of DCCT and the facilitator who would ensure that we avoid the pitfalls of a failed solution. The built relationship between DCCT and the facilitator provided us with access to the e-Learner classes where we worked. Without them, we would not have users to test our research questions.

Working with DCCT had consequences for our research. We had to be mindful of their culture and ethics while assisting them with their computer related difficulties as much as they assisted us with our research. The implication of which allowed us to engage with DCCT in a democratic and empowering way. We had to respect the working hours of DCCT and conduct our engagement with users in the weekly e-Learner classes. Our work was not only confined to research activities but also helping DCCT staff members with their activities they could benefit from our technical knowledge. This ethics of reciprocity (also stated in Section 1.4) strengthened the already established long-term relationship with DCCT.

Data gathering became much easier once the author became actively involved in the e-Learner classes as an assistant. We were made aware of the literacy backgrounds of the Deaf learners. The involvement in the e-Learner classes gave us an appreciation for DCCT goals for the computer literacy project, and so we considered the time spent assisting in the classes compared to collecting data.

8.5 Summary of Contributions

Our contributions, on a primary level, show a technical design which has demonstrated support by answering the first research question. We implemented a system to support Deaf learners and their facilitator. We have shown that our system removed the need for the facilitator to interpret written text into SASL. In addition, the authoring system allows the facilitator, as a domain specialist, to author appropriated lesson content for the Deaf learners. This ties together with our theme of support.

Deaf learners with basic exposure of computer literacy skills showed higher individual work paces compared with learners with no prior exposure. Our system has demonstrated to work on commercially available mobile devices which were available to Deaf people. The Deaf learners are not constrained to accessing the lesson content only when the facilitator is present. This has given them the flexibility to use our system as a distance learning tutoring system. Further, lesson content stored locally on the device to avoid data costs.

On a secondary level, we see from a methodological point of view, the intense engagement with the community as empowered partners participating in the design process resulted in a solution that was readily acceptable. In addition, the introduction of a system structure where a Deaf learner was an assistant facilitated sustainability of the solution. Moreover, if the facilitator would be absent or to leave, ownership of the solution would continue by the community. While this may appear to be related to Prahalad's concept of '*deskilling*' [84], we prefer to regard it as adapting the ICT solution to match the skills of our community.

8.6 Future Work

Future work could expand our work to other institutions training Deaf people in computer literacy skills. This would allow for an increased number of Deaf participants in the study and collect substantial quantitative data in addition to qualitative data.

The Deaf learners demonstrated the capacity to use our system, and the facilitator able to create lessons using the authoring tool. The rest of the lessons in the e-Learner manual would have to be translated into SASL and recorded with the approval from and in collaboration with Computer 4 Kids. Furthermore, in order to generalise our solution, our system needed be tested with other institutions that teach Deaf people computer literacy skills. The lesson content is easily replaceable because of its ‘plug-and-play’ nature and recording signed language videos happens once for every national sign language.

The assistant in Cycle Four demonstrated the capacity to facilitate the classes. We would like in future to establish if the assistant can take over facilitating the e-Learner classes and use the authoring tool to create lessons. At present, a new approach called *Train the Teacher* (TOT) where the facilitator is training an advanced Deaf learner to teach a new group of Deaf learners who have started the e-learner classes. TOT is the next phase and we would like to investigate further in a longitudinal study to determine the learning effect of using our systems (authoring tool and mobile) in the training.

Our focus in this dissertation was on the user interfaces and not on learning theories such as constructivism and behaviourism as well as instruction design methods. Furthermore, the discussion of video as an instruction medium was not highlighted which we considered it for further investigation together with learning theories.

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Appendix A

Information sheet

The information below describes the project. The information is to be signed by a professional SASL interpreter who will interpret it for Deaf participants.

1. What is this project about?

- I am going to tell you about a mobile phone project for Deaf people.
- This project will enable you to learn computer skills at your own pace with or without the help of a teacher.

2. Who is running this project?

- We are computer scientists from the University of Cape Town.
- You might know Edwin Blake. He is the project leader.
- The student responsible for this particular project is George Ng'ethe (George).
- You know Meryl Glaser who is the teacher of the computer skills course.

3. What do we want to achieve?

- We want to improve learning of computer skills amongst Deaf people.
- All of you use SASL to communicate and learn using it.
- We want to design a system that can make it easier for you to learn or improve computer literacy skills.

- Most of you use mobile phones.
- So we would like to implement an application for a mobile phone that you can use to learn computer skills.
- This will not cost anything to see the video instructions on the phone.
- However, if you do not understand the instructions and want to ask a question; a teacher has to be present to answer you question if you are learning in a classroom.
- The application should allow you to learn computer literacy skills at you own pace independent of the teachers help in a class.

4. What will we do?

- We will design and build an application to run on the mobile phone.
- The application will have pre-recorded SASL videos of computer literacy lessons organized in topics from easy topics to difficult ones.

5. Benefits

- Once the application is developed to a certain stage and put on a mobile phone, you can use it in a computer lab to teach yourself during your own time.
- We plan that the application should provide all the information needed to learn computer skill in SASL videos. It is like reading a book.

6. Risks and difficulties

- There is no risk or difficulties in the experiment. There is no question in the session that will require you to reveal personal information.

7. Withdrawal and confidentiality

- All information and videos recorded during the research session will be kept confidential and will be stored on a computer with a password which the research only knows.

- Your identity will not be revealed to the public unless we receive permission from you.
- Please be informed you have the right to withdraw from any research session by informing the researcher.
- As soon as you withdraw, all material about your information will be destroyed.

8. Dissemination of study results

- All information will be disseminated when the study is completed in the form of conference papers at various conferences.
- The data may be used towards the awarding of higher degree to the researcher involved in the study.
- Deaf participants will be kept informed via several presentations at DCCT at some time in the project.

For further information, please do not hesitate to contact:

George Ng'ethe and Edwin Blake

Dept. of Computer Science

University of Cape Town

Private Bag X3

Rondebosch 7701

Email: georgegitz@gmail.com / edwin@cs.uct.ac.za

Appendix B

Consent Forms

B.1 Interpreter consent form

I, _____, fully understand the mobile support for Deaf computer literacy communication aid for Deaf people project and agree to interpret. I understand South African Sign Language and will provide sign language translation. I am bound by Deaf South Africa's (DEAFSA) code of ethics for SASL interpreter to adhere all aspects of the Code of Ethics at all times during and after assignments; keep all assignment-related information strictly confidential and adhere to professional standards of confidentiality; and render the message faithfully, always conveying the content, intent and spirit of the speaker using the language most readily understood by the person(s) whom they serve.

I also pledge that I have explained all the aspects of the research to the participants.

For further information, please do not hesitate to contact:

George Ng'ethe and Edwin Blake

Dept. of Computer Science

University of Cape Town

Private Bag X3

Rondebosch 7701

Email: georgegitz@gmail.com / edwin@cs.uct.ac.za

Signature (Participant) _____

B.2 Deaf Consent form

I, _____, fully understand the mobile support for deaf computer literacy communication aid for Deaf people project and agree to participate. I understand that I can withdraw from the study at any time, and any information collected pertaining my contribution will be destroyed at once. I also understand that all information that I provide will be kept confidential, and that my identity will not be revealed in any publication resulting from the research unless I choose to give permission. I acknowledge that all information attained in this study or test will be stored on a computer that has a password that is only known by the researcher. Furthermore, all recorded interview media and transcripts will be destroyed after the project is completed. I am also free to withdraw from the project at any time. I understand that an interpreter will be used for this trial and the information he/she translates will be kept confidential and not repeated.

For further information, please do not hesitate to contact:

George Ng'ethe and Edwin Blake

Dept. of Computer Science

University of Cape Town

Private Bag X3

Rondebosch 7701

Email: georgegitz@gmail.com / edwin@cs.uct.ac.za

Signature (Participant) _____

Appendix C

Evaluation guide

C.1 SIGN LEARNER EVALUATION MAY 14, 2014

Lessons Special Keys and Files and Media

Notes:

- Note down how long participants take long to find item
- Note what takes them the longest, what takes the quickest.
- Ask participants why they followed certain actions, note what they say.

TASK 1

Today you want to learn a computer lesson about special keys on a keyboard. Can you use the mobile application Sign Learner to find the lesson on special keys?

TASK 2

You want to find out how long the special keys lesson is. Can you find the number of the last task step in the lesson?

Things to look out for: Do the participants notice the list

TASK 3

You want to start the lesson on special keys. Can you use the mobile application find the start of the lesson to begin learning?

Things to look out for: Do they scroll to the beginning of the list to locate the start of the lesson? Where do they click on the list? Give the participants 20 minutes to do the lesson and stop.

TASK 4

Now you change your mind and want to learn about files and media. Can you use the mobile application to locate the files and media lesson?

Things to look out for: Can they find their way back to the list of lessons to find locate the lesson files and media? Do they need prompting? Is the navigation clear? Try to note what is pressed on the screen and the result.

TASK 5

Start the lesson files and media and finish it.

Things to look out for:

- Which participant finishes first and who finishes last? Note the time difference.
- The number of times a participant asks for help.
- Number of times a participant asks for help. Note what kind of help (Instructional (SASL video) or navigational)
- Number of times the teacher helps the learner with either kinds of errors.
- Number of errors per participant (Instructional or navigational).

TASK 6

Once you are done with the lesson. Close the mobile application.

Things to look out for: Can they find the how to exit the application? Is the information clear how to close the application?

FOCUS GROUP DISCUSSION

1. Is there anything you like about the mobile application?
2. Did you get confused using the mobile application?
3. Was it easy to follow the instructions on the screen?
4. Was it easy to complete a lesson using the application?
5. Was the information well organized?
6. Is there anything you would want to add?

Appendix D

Deaf Participant lesson Screen shots



Figure D.1: Organisational chart created by participant 1

My Organization

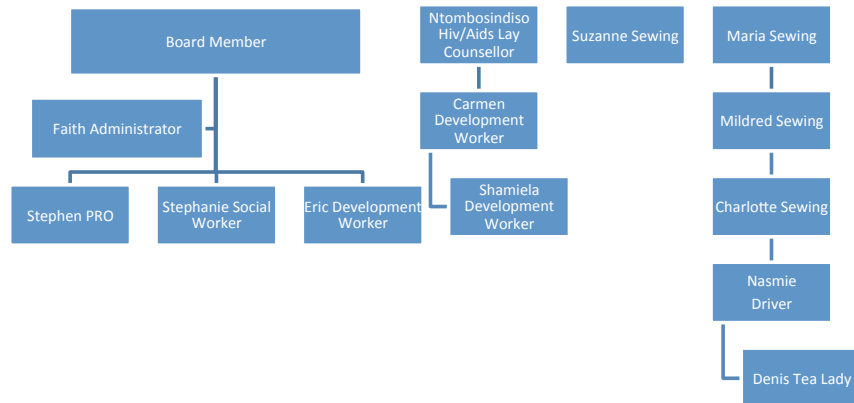


Figure D.2: Organisational chart created by participant 2

my organization

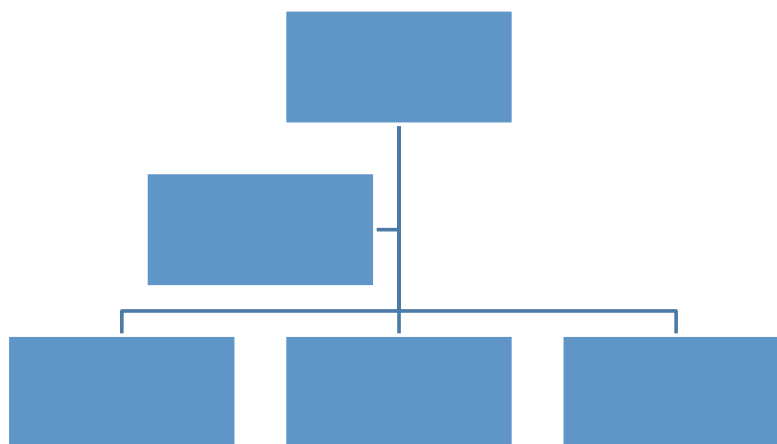


Figure D.3: Organisational chart created by participant 4

Appendix E

Non-Disclosure Agreement

This Non-disclosure Agreement (this Agreement) is made effective as of July 26, 2013 (the Effective date) by and between George Ngethe (the Owner) and _____ (the Recipient), of Supporting Computer Literacy Training in Sign Language (SCLTSL) project.

The Owner has requested that the Recipient will protect the confidential material and information which may be disclosed between the Owner and the Recipient. Therefore, the parties agree as follows.

1. **CONFIDENTIAL INFORMATION.** The term Confidential Information means any information or material which is proprietary to the Owner, whether or not the owned or developed by the Owner, which is not generally known other than by the Owner, and which the Recipient may obtain through any direct or indirect contact with the owner.

Confidential Information includes without limitation: Copyrights and other intellectual property and other proprietary information.

2. **PROTECTION OF CONFIDENTIAL INFORMATION.** The Recipient understands and acknowledges that the Confidential Information has been developed or obtained by the Owner by the investment of significant time, effort and expense, and that the Confidential Information is a valuable, special and unique asset of the Owner which provides the Owner with a significant competitive advantage, and need to be protected from improper disclosure. In

consideration for the receipt by the Recipient of the Confidential Information, the Recipient agrees as follows:

- **No Disclosure.** The Recipient will hold the Confidential Information in confidence and will not disclose the Confidential Information to any person or entity without the prior written consent of the Owner.
- **No Copying/Modifying.** The Recipient will not copy or modify any Confidential Information without the prior written consent of the Owner.
- **Unauthorized Use.** The Recipient shall promptly advise the Owner if the Recipient becomes aware of any possible unauthorized disclosure or use of the Confidential Information.

3. **UNAUTHORIZED DISCLOSURE OF INFORMATION - INJUNCTION.** If it appears that the Recipient has disclosed (or has threatened to disclose) Confidential Information in violation of this Agreement, the Owner shall be entitled to an injunction to restrain the Recipient from disclosing the Confidential Information in whole or in part. The Owner shall not be prohibited by this provision from pursuing other remedies, including a claim for losses and damages.
4. **RETURN OF CONFIDENTIAL INFORMATION.** Upon the written request of the Owner, the Recipient shall return to the Owner all the written materials containing the Confidential Information. The Recipient shall also deliver to the Owner written statements signed by the Recipient certifying that all materials have been returned with (5) days of receipt of the request.
5. **NO WARRANTY.** The Recipient acknowledges and agrees that the Confidential Information is provided on a AS IS basis. THE OWNER MAKES NO WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THE CONFIDENTIAL INFORMATION AND HEREBY EXPRESSLY DISCLAIMS ANY AND ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL THE OWNER BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, OR COSEN-

QUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE PERFORMANCE OR USE OF ANY PORTION OF THE CONFIDENTIAL INFORMATION. The Owner does not represent or warrant any product or business plans disclosed to the Recipient will be marketed or carried out as disclosed, or at all. Any actions taken by the Recipient in response to the disclosure of the Confidential Information shall be solely at the risk of the Recipient.

6. **LIMITED LICENCE TO USE.** The Recipient shall not acquire any intellectual property rights under this Agreement except the limited right to use the as set forth above. The Recipient acknowledges that, as between the Owner and the Recipient the Confidential Information and all related copy rights and other intellectual property rights are (and at all times will be) the property of the Owner, even if suggestions, comments and/or ideas made by the Recipient are incorporated into the Confidential Information or related material during the period of this Agreement.
7. **INDEMNITY.** Each party agrees to defend, indemnify, and hold harmless the other party and its officers, directors, agents, affiliates, distributors, representatives, and employees from any and all third party claims, demands, liabilities, costs and expenses, including reasonable attorneys fees, cost and expenses from the indemnifying party's material breach of any duty, representation, or warranty under this Agreement.
8. **GENERAL PROVISIONS.** This Agreement sets forth the entire understanding of the parties regarding confidentiality. The obligations of the confidentiality shall survive 1 month(s) from the date of disclosure of the Confidential information. Any amendments must be in writing and signed by both parties. This Agreement shall be construed under the laws of the Republic of South Africa. This agreement shall not be assignable by either party. Neither party may delegate its duties under this Agreement without the prior written consent of the other party. The confidentiality provisions of this Agreement shall remain in full force and effect at all times after the effective date of this

Agreement. If any provision of this Agreement is held to be invalid, illegal or unenforceable, the remaining portions of this Agreement shall remain in full force and effect and construed so as to best effectuate the original intent and purpose of this Agreement.

OWNER:

George Ng'ethe

Signature _____

Date: 26 July 2013

RECEIPIENT:

Name: _____

Signature _____

Date: _____

Appendix F

Ethics Clearance

Faculty of Science
University of Cape Town
RONDEBOSCH 7701
South Africa

E-mail: richard.hill@uct.ac.za
Telephone: + 27 21 650 2786
Fax: + 27 21 650 3456



27 September 2013

Mr George Ng'ethe
Department of Computer Science
University of Cape Town

Dear Mr Ng'ethe

MOBILE SIGN LANGUAGE SUPPORT FOR DEAF COMPUTER LITERACY

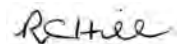
I am pleased to inform you that the Faculty of Science Research Ethics Committee has approved the above-named application for research ethics clearance, subject to the conditions listed below. You are required to:

- implement the measures described in your application to ensure that the process of your research is ethically sound, and
- uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: please contact me if you need advice on ethical issues that arise.

Your approval code is: FSREC 027– 2013

I wish you success in your research.

Yours sincerely



Dr Richard C Hill
Chair: Faculty of Science Research Ethics Committee

Appendix G

Guidelines for Authoring

The following are guidelines for authoring content for Deaf adults using SignSupport.

G.1 Generation of conversation script

To generate a conversation script for authoring, these are the steps to follow:

1. Select the lesson to record. The lesson chosen should be a balance of introductory information containing definitions and explanations and task that a learner should perform.
2. Write down all sentences as a numbered list. The list helps identify the sentence and makes it easier for an interpreter to sign an individual sentence.
3. Identify and simplify complex sentences (see Section). Sentences containing multiple clauses joined using conjunctions should be separated and written down as an individual point on a numbered list. This ensures each sentence has one subject and a verb that either informs or asks a learner to do something. For example, sentences that contain a task should tell the learner to perform a single task. Repeat this step until all sentences are simple which may lengthen the numbered list.
4. Verify that all sentences are in the numbered list are simplified. This step requires a domain specialist to verify that the content to be authored can be understood.

Once the conversation script has been generated, it can then be use for recording the sign language videos. In the section below we provide additional guides for complex sentences, contextual information and discourse markers.

G.1.1 Complex Sentences

Complex sentences should be broken down into basic single subject - verb structure that takes one point. Each sentence should consist of only once action for example, “Open Microsoft Word.” This sentence has once task for a learner to perform which prevents cognitive overload on the Deaf learner.

G.1.2 Contextual information

Contextual information for example navigational Signed language videos that provide additional information such as navigational for example how what buttons to press to access a lesson and. These can be included as part of the lesson or as part of system structure as a wizard for first time users.

G.1.3 Discourse Markers

Discourse markers are necessary addition to the content. These marker ensure that the learner has a cue to progress or backtrack between lesson content. The discourse marker to be incorporated are identified with the help of a domain specialist and written down in a numbered list. These are then recorded as separate videos that will be added to the lesson content in Section G.1.