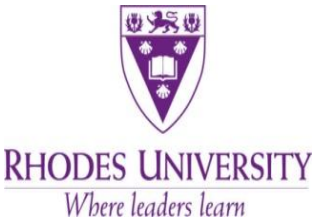
A Platform for Computer-assisted Multilingual Literacy Development



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Abstract

FundaWethu is reading software that is designed to deliver reading lessons to Grade R-3 (foundation phase) children who are learning to read in a multilingual context. Starting from a premise that the system should be both educative and entertaining, the system allows literacy researchers or teachers to construct rich multimedia reading lessons, with text, pictures (possibly animated), and audio files. Using the design-based research methodology which is problem driven and iterative, we followed a user-centred design process in creating FundaWethu. To promote sustainability of the software, we chose to bring teachers on board as "co-designers" using the lesson authoring tool. We made the authoring tool simple enough for use by non computer specialists, but expressive enough to enable a wide range of beginners reading exercises to be constructed in a number of different languages (indigenous South African languages in particular). This project therefore centred on the use of design-based research to build FundaWethu, the design and construction of FundaWethu and the usability study carried out to determine the adequacy of FundaWethu.

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"*He fills my life with good things. My youth is renewed like the eagles!* [Psalms 103:5, NLT]. "

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CHAPTER 1: INTRODUCTION

Literacy can be simply defined as the ability to read and write. For PIRLS [1] (Progress in International Reading Literacy Study), reading literacy is defined as the ability to understand and use those written language forms required by society and/or valued by the individual. Proficient reading at the foundation phase (first four years of schooling from Grade R to Grade 3) is a foundation for further learning [2].

PIRLS is an international reading assessment conducted at the fourth grade designed to measure trends in children's reading literacy achievement and to collect information about the policy and practices related to learning to read and reading instruction [3]. The PIRLS 2006 assessment showed that South Africa fared worst out of forty six educational systems around the world in reading literacy [4]. 80 percent of South African 4th graders assessed showed that they did not have the most basic literacy skills compared to ninety-nine percent basic literacy in countries like Belgium, the Netherlands and Lithuania. This is the reason why we are targeting children in the foundation phase of education, because beyond this point, a child must read with ease and understanding to take advantage of the learning opportunities in fourth grade and beyond; in school and in life [5].

Young readers can construct meaning from a variety of texts. They read to learn, to participate in communities of readers in school and everyday life, and for enjoyment [1]. Reading can be generally defined as a process which involves the reader, the text and the interaction between the reader and text [6]. Computer Assisted Instruction (CAI)) makes this interaction more interesting and engaging through the use of multimedia to illustrate reading concepts. Learning to read and write should start at home, long before children go to school but this is often not the case especially in poor communities.

In developing communities, children grow up with very little exposure to print until they reach Grade 1 when they are immersed into the reading world in a bilingual setting. This project is therefore driven towards supporting bilingual reading (mother tongue and a second language). Interestingly, and contrary to popular opinion, some researchers [7] have shown bilingual reading to be an effective way of getting children to read the second language with ease. Research shows that the knowledge children get through their first language helps them read, write, and speak in English faster than if they didn't have home language support [7]. In

a sample of forty two thousand language minority students from across the United States, Thomas and Collier found that when children were schooled bilingually, they would take only four to seven years to reach the 50th percentile on standardized tests in their second language, English [7]. Moreover, the children were on or above grade level in their first language as well. However, when there was no schooling in the home language, the children would need seven to ten years to reach those levels of performance.

In South Africa, the shortage of qualified teaching staff is still a big setback in reading literacy. In most schools in poor communities, the child-teacher ratio is very high and it makes it difficult for teachers to concentrate on individual children. This has led to the recruitment of non-teaching volunteers to assist in reading projects which are support systems for what children learn in the classroom.

Although the volunteers are trained, experience has shown that they cannot be relied upon and that they do not give the kind of support that a trained teacher does. As a result our project, which is aimed at creating a reading literacy delivery platform, will be designed in such a way that educators will create the lessons and we will deliver them using multimedia, while collecting data to feed back to the lesson designers.

Research has been carried out to determine or assess the effectiveness of various kinds of computer uses, programs and interventions in improving reading achievement [6]. In spite of this, some of these programs have failed to include a sound theoretical base in terms of how reading should be taught and what should be emphasized in a reading program [6]. This is the reason why, in this project, we will engage the education specialists in designing the lessons which our system will deliver.

1.1 Reading in South Africa

Illiteracy in South Africa is a deeply rooted social phenomenon and is threatening the transformation and development of the nation [8]. The South African government has a number of policies in place with regard to education. We are particularly interested in two of them:

1.1.1 Policy for Early Childhood Development (ECD)

This policy emphasises the critical role of ECD as a foundation for lifelong learning. Development applies to all processes by which children, from birth to age nine, grow and thrive, mentally, emotionally and socially [8]. Reading is a central activity and is essential to this development [9].

1.1.2 Language in Education Policy

The Language in Education Policy of July 1997 forms part of a national language plan for South Africa which draws on the constitutional provisions that recognise cultural diversity as a valuable national asset, promote multilingualism, support the development of official languages and respect all languages in the country [8]. One of the goals of this policy is to facilitate national and international communication through promotion of bi- or multilingualism through cost efficient and effective mechanisms.

These two core policies therefore support the aims of this project

1.2 CAI in South Africa

According to a 2007 survey [10] published in January 2009 by the Department of Education, more than 85 percent of learners attend public schools in South Africa. There are 12 401 217 learners in ordinary schools (mainstream primary and secondary education) who are served by 394 225 educators. The learner to educator ratio is approximately 31.5:1 ranging from 28.9:1 in the Free State to 33.2:1 in Limpopo. These statistics are shown in Table 1 below. The high learner to educator ratio means that it is difficult for teachers to give children individual attention which may result in poor learning. This is especially critical at the foundation phase where children are introduced into the education system.

Computer-based reading programs are effective and fairly quick in addressing the reading problems of young learners if they are used properly. Since children in South Africa are among the worst readers in the world, computer-aided technology could be used as the medium which young learners can identify with to cultivate and re-establish a love for reading. This has not been easy in South Africa due to lack of access to technology. According to Intel Education [11], 39.2 percent of schools have computers, while only 26.5 percent have computers for both teaching and learning, nationally. A survey in 2000 found

that the principal factors preventing schools from using computers as a tool for teaching and learning included [11]:

- insufficient funds
- inadequate numbers of computers
- lack of computer literacy among teachers
- lack of subject teachers trained to integrate computers into different subject areas and
- lack of properly developed curriculum for integrating ICT into subject teaching

This has a profound effect in poor communities where the only likely place to access a computer is the school because having a computer at home is out of reach for many. The use of technology in education could thus become more effective with the introduction of more computers in learning institutions and adequately training teachers to use the technology.

Province	Learners		Educators		Schools		LER	LSR
	Number	As % of National Total	Number	As % of National Total	Number	As % of National Total		
Eastern Cape	2 136 713	17.2	66 163	16.8	5 834	22.4	32.3	366
Free State	680 777	5.5	23 570	6.0	1 744	6.7	28.9	390
Gauteng	1 883 538	15.2	63 216	16.0	2 397	9.2	29.8	786
KwaZulu-Natal	2 848 652	23.0	88 042	22.3	6 057	23.2	32.4	470
Limpopo	1 816 230	14.6	54 769	13.9	4 140	15.9	33.2	439
Mpumalanga	1 054 085	8.5	32 276	8.2	1 973	7.6	32.7	534
North West	747 248	6.0	25 701	6.5	1 780	6.8	29.1	420
Northern Cape	265 647	2.1	8 580	2.2	613	2.4	31.0	433
Western Cape	968 327	7.8	31 908	8.1	1 527	5.9	30.3	634
National	**12 401 217**	**100.0**	**394 225**	**100.0**	**26 065**	**100.0**	**31.5**	**476**

Table 1: Number of learners, educators and schools, and learner-to-educator ratio (LER) and learner-to-school ratio (LSR), in the ordinary public and independent school sector, by province, in 2007 [10]

Although many educationalists still doubt the benefits of technology in fostering literacy skills, Blok et al. [12] reviewed 42 CAI studies carried out since 1990 and found that the use of computer software programs can have a positive impact on the development of literacy skills. As the name suggests, assistive technology does not cure or eliminate learning difficulties but it helps a learner reach their full potential by reinforcing their strengths and bypassing areas of difficulty [13].

1.3 How to make CAI work in Schools

In particular, computer programs may be especially beneficial for struggling students by providing the opportunity for ample practice of skills [14]. For this reason, we chose to intervene in a group of struggling readers at a local school. However, there are certain implementation measures that should be taken in order for any intervention to be effective and to benefit the targeted group. In doing this there are significant challenges (Table 1) that are encountered. Macaruso and Hook [15] discuss three of these challenges.

1.3.1 Provide sufficient technical support

Among many other factors, competent staff is essential to the successful deployment of Information and Communications Technology (ICT) in a school [16]. One of the initial challenges with regard to implementing computer programs in schools is the technology itself [17]. Limited technical support decreases the effective use of computer programs in schools. Teachers without much technical expertise may have a difficult time running the software and troubleshooting when there are problems. While training may be essential for the teachers to gain technical skills, the fear of running into technical difficulties often makes teachers shy away from anything technical. One solution to this could be to have dedicated technical personnel who handle the hardware and installation concerns. Although this takes away the expectation for teachers to be technical experts and allows them to concentrate on constructive ways to use the software, it would not be feasible in a marginalized school because of the expenses involved. Peer to peer mentoring for teachers could therefore be a more effective way of training them to use the software because they are more likely to be at ease with one of their own.

1.3.2 Properly integrate software into the curriculum

ICT initiatives should be properly integrated into the curriculum such that they do not increase the workload of the teachers. Technology is intended to play an assistive role to the students and teachers, it is important to ensure that this is maintained so that ICT initiatives are not seen as a source of stress [15]. This can be achieved by bringing the teachers on board and not imposing things on them. This collaboration is achieved well by using design-based research. Teachers need to maintain control and ownership over their work and classes in order for the initiatives to be sustainable. This means that their work and opinions should be

taken seriously. The degree to which teachers are invested in using the software programs in their classes is also a challenge in the successful integration of ICT in education. Wilson-Strydom and Thomson [18] suggest that integration is in two parts, that is, the stages of integration (adoption) and the type of integration (use). A UNESCO 2002 report [19] on ICT curriculum and teacher development suggests a four stage continuum of ICT integration:

- *Emerging*

  Schools at the beginning stages of ICT development demonstrate the emerging approach. Such schools begin to purchase some computing equipment and software or they have them donated by well-wishers [19]. In this phase, administrators, and teachers are just starting to explore the possibilities and consequences of using ICT for school management and learning but they are still firmly grounded in traditional, teacher-centred practice [19]. This is the stage where schools in marginalised areas are likely to be and the use of ICT has a status role. Our target school, for example, had some computers donated but they were sitting idle in the lab after a lightning episode that damaged most of them.

- *Applying*

  In this phase schools have gained some understanding of the contribution of ICT to learning. Administrators and teachers use ICT for tasks already carried out in school management and in the curriculum [19]. At this stage it is mostly the teachers that are learning how to use ICT in an educational setting. This is the trend that we noticed after the computers at our target school were repaired. Teachers are aware that ICT can be used for learning but they used it mainly for administrative purposes with children having very little or no access to the computers.

- *Infusing*

  The infusing approach involves integrating ICT into the curriculum, and is seen in those schools that now employ a range of computer-based technologies in laboratories, classrooms, and administrative offices [19]. Teachers also begin to explore new ways in which ICT changes their personal productivity and professional practice.

- *Transforming*

  Schools that use ICT to rethink and renew school organization in creative ways are at the transforming stage [19]. ICT becomes ubiquitous (it is thoroughly integrated

into daily personal productivity and professional practice). In these schools, ICT is taught as a separate subject and is incorporated into all vocational areas [19]. These schools become centres of learning for their communities.

The need for teachers to be technologically competent cannot be emphasised enough. Wong [16] made reference to Moursund's definition of an eight-level "Stages of Concern" model or proficiency model (Table 2) which teachers go through in order to reach the leadership level. It is at this level where the effect of technology in education is maximised. In marginalised schools, most teachers are at the personal use level where they have basic typing, printing and copying knowledge for administrative purposes.

Stage	Knowledge	Concern
1. Awareness	Became aware of educational use of computers but techno-phobic	how to become familiar with hardware and software
2. Informational	Gained novice level of ICT skills and knowledge but have insufficient confidence	how to use ICT in instructional work
3. Personal	started to use ICT in profession	the effect of ICT to personal and professional life
4. Time	spend some time using ICT professionally	time needed to learn and update computer knowledge
5. Consequences	making certain use of ICT in profession	the effects of various ICT tools on students and own profession
6. Collaboration	occasionally help colleagues in solving ICT problems	doing more extensive work with peers for the benefits of both
7. Refocusing	making routine use of IT in profession and help colleagues learn ICT	learn new ways to use and expand the horizon in ICT
8. Leadership	being the technology leader	maintain and improve leadership and professional development skills in school, district and beyond

Table 2: Stages of acquisition of IT knowledge for educators

1.3.3 Establish strong usage patterns

A published study by Macaruso et al. [15] shows that successful implementation of CAI depends a lot on high usage patterns. The study was carried out with first-grade student participants in an urban public school; the students received daily phonics lessons and software programs were used to supplement this classroom instruction [15]. The software was designed for regular weekly use (2 to 4 sessions of twenty–thirty minutes each). Based on these guidelines, completion of sixty or more sessions over the school year reflected high use while forty to sixty sessions reflected moderate use. Initial results of the study showed that students in experiment classes (using reading software), and in control classes, all made significant gains in reading. For struggling readers however, the improvement in the experiment classes was greater than that of the control classes [15]. Because of tight school schedules and that CAI is still an extra curricula program in most schools in South Africa, finding sufficient time to work with learners is a challenge. This time limitation ultimately affects the effectiveness of CAI interventions.

The three factors that determine the success of CAI in schools above do not work in isolation but when all of them are integrated, the chances of a successful CAI intervention are high [15]. There are several obstacles that can get in the way of effective use of ICT and the Department for Education and Skills (DfES) 2001 report [20] summarised them into six categories (Table 3).

1	Lack of availability of ICT for teachers, both for management and curriculum purpose, in addition to limited accessibility from home for teachers
2	"Skill gap", probably resulting from the lack of availability, accessibility or training
3	Lack of sharing of experiences, expertise and software between schools
4	Lack of accessibility of web-based resources
5	Lack of on-site and remote (e.g. web-based, telephone) technical support
6	Lack of central direction in schools about the achievable targets of and limits to ICT

Table 3: Obstacles to the effective use of ICT in schools in England and Wales [20]

Summary

In this chapter we explored three main themes. Firstly, the poor achievement of readers in South African schools as evidenced by the PIRLS study. This is caused by various factors which include lack of financial and human resources. Secondly we looked at ways in which these results could be improved and CAI has proved to be a valuable tool in improving reading competence of struggling readers and reading beginners. Finally we discussed measures that have to be put in place in order for CAI to be a success.

This project had three major themes: the Design-based research methodology and its use for building systems like FundaWethu (we have dubbed our system FundaWethu which is isiXhosa for "read mate!"), the design and construction of the artefact, and the usability study / intervention that we did. We discuss these themes in chapters 3, 4, 5 and conclude in chapter 6.

CHAPTER 2: BACKGROUND

This chapter explores some of the background and literature around the use of software and games in an educational setting. The field is vast, so we focus particularly on those aspects that are most relevant to FundaWethu.

2.1 Research problem

Our current bilingual foundation phase, with its many resourcing challenges is producing poor literacy results as shown by the PIRLS 2006 assessment. CAI could help as long as it includes a sound theoretical base on how to teach reading [6]. Most of the available systems are either very expensive, they often have a weak sound theoretical base, or they come in standard packages which educators who are non-programmers cannot change or update for local languages, local accents and conditions. We believe that a new system is needed to address the local literacy issues. These include language diversity, print reading material inaccessibility due to poverty and high student-teacher ratios especially in public schools [10].

Unlike most off-the-shelf reading software, FundaWethu is a dual-purpose platform, to be used both for reading development and research into reading skills acquisition. The children interact with just one of the components – the presentation engine. In developing this system, we pursued the edutainment theme. Jegers and Wiberg [21] define edutainment as a blend of education and entertainment, pursued in multimedia software. Software technologies that provide easier and quicker game development platforms for interactive games, for example, Microsoft XNA, are becoming more available. This project will therefore take advantage of such emerging technology to create a reading program that will provide effective learning, effective teaching and effective communication of the content [21].

Multimedia hardware which is an important component of edutainment is also becoming more accessible and will help us to deploy FundaWethu at low costs. One example of this hardware is the NComputing X300 desktop virtualization kit [22] which enables up to seven users to share one PC. With limitations in computing and financial resources, we envisaged that this type of hardware could help us cut costs of a laboratory for running FundaWethu. On the education front, FundaWethu will allow educators to design the lessons and update them

as they deem necessary, and gather and analyze performance data. In this way, the system will also serve as a reading literacy research platform for educators because they have a measure of control of the lesson delivery.

In support of home language education at the foundation phase, our goal was to produce a system that can author and deliver reading lessons in different languages, specifically indigenous South African languages. It was envisaged that some activities may be drill-and-practice, with the primary purpose of improving skills in the child, while other activities may be more experimental, designed to collect raw data for the researchers. One example of a local reading program that supports indigenous languages is the Macmillan Talking Stories (MTS) by Kathy McCabe [23]. This is an inspirational e-Learning initiative that is designed to boost grade 1 to 3 learners' literacy rates. MTS covers both the Home Language and First Additional Language curricula for English, Afrikaans and IsiXhosa, making it ideal for both Home Language and First Additional Language learners. Unlike MTS, FundaWethu will offer the flexibility of allowing educators to design and update the lessons to suit the learners they are working with.

IsiXhosa is an agglutinative language [24] (languages in which most words are formed by joining morphemes together) featuring an array of prefixes and suffixes that are attached to root words. Verbs are modified by affixes that mark subject, object, tense, aspect, and mood, for example, **um**ntwana, **aba**ntwana or **in**doda, **am**adoda. English on the other hand tends more towards an isolating language [25] in which words are largely composed of a single morpheme (smallest linguistic unit that has semantic meaning). For example, “boy” consists of one morpheme; “boy” whereas “antigovernment” has three morphemes namely “anti”, “govern” and “ment”. A growing realization among education specialists is that, teaching reading in other languages may need to be approached differently: a simple re-targeting of the teaching methods that work in English will not necessarily be the most effective approach for other languages [26]. Our system will hopefully enable researchers to formulate lessons or experiments to explore research questions like this.

Most of the reasonably good reading software, for example, ClaroRead and AceReader, is very expensive. By contrast, FundaWethu is released under a very permissive Open Source licence. Most purchased reading software comes in a standard package which cannot be altered by educators in any way to suit the needs of the children or correct existing mistakes,

e.g., grammar or spellings. In a study carried out at an Afrikaans school in South Africa [27], facilitators outlined this as a negative factor when using technology assisted reading to improve reading skills. Facilitators commented that there were limitations in the design of the program in that they had no access to the framework to correct or update the content [27]. FundaWethu on the contrary, has a simple lesson construction mode which allows the direct involvement of education specialists. In this way, the educators will construct the lessons and update them without any programming skills required. Our thesis or research question is therefore crystallised as follows:

> *Can we build a cost-effective, fun, language-adaptive and flexible lesson authoring, and delivery platform that could assist teachers, researchers and learners involved in bilingual foundation phase teaching?*

2.2 The use of technology in education

The role that technology plays in education has always been a debatable issue. The essence of the debate about the use of computers by young children mainly focuses on the allegation that most of the educational software is of poor quality and does not contain a substantially sound theoretical base to foster learning [28]. Computer assisted instruction has been very popular during the last two decades, and scholars agree on the feasibility of applying computers in reading instruction under appropriate designs [29, 30]. In the 1980s there was vigorous debate about the role of technology, and computers in particular, in early childhood curriculum. Some early childhood educators [28] were of the opinion that young children should not use computers because they:

- were too abstract
- minimized the role of teachers
- did not assist children to work collaboratively and
- were used with programs that were considered to be developmentally inappropriate.

On the other hand, some researchers [28] argue that the use of technology in education will not only foster education in different areas but it will prepare children to operate in a technologically advancing environment with ease. Some pro-technology researchers [31] also conceded that for technology to be used successfully in the education of young children, the following guidelines have to be followed:

- Teachers should join forces with parents to choose developmentally appropriate software for young children. In our poor communities, this is not feasible because

most of the parents are illiterate and have never used a computer before. So in this case, the responsibility to choose educational software would be on the teacher. That said we still face challenges where the teachers are computer illiterate and therefore cannot offer the children appropriate technological help. This leads us to our second guideline;

- Support is needed to assist the educators to become confident and competent with computer technology.
- Recognise that some software applications could enhance cognitive and social skills.
- Computers should be used as a supplement not a replacement to traditional early childhood materials because no matter how good the computer program is, it cannot replace the human influence of a teacher.

Yelland [28] provides an overview of numerous studies that examine the use of computers in early childhood education. Research has demonstrated that the use of technologies can raise the level of early childhood curriculum so that young children can not only experience concepts that were previously well beyond that expected of them, but that they could deploy sophisticated strategies and work collaboratively with others in new and dynamic ways in technological environments [28, 32].

2.2.1 E-learning

E-learning is technology-based learning covering many forms of learning methodology including computer-based learning, web-based learning, virtual classrooms and digital collaboration. Learners can study via all kinds of electronics media such as the Internet, intranet, satellite broadcast, audio/video tape, interactive TV and CD-ROM [33]. E-learning has the following features:

- Includes content relevant to the learning objective.
- Uses instructional methods such as examples and practice to help learning.
- Uses media elements such as words, sounds, video and pictures to deliver the content and methods.
- Builds new knowledge and skills linked to individual learning goals or to improve organizational performance.

E-learning is made up of 3 elements [34]:

- *What*: e-learning courses include both content and instructional methods that help people learn the content.

- *How*: e-learning courses are delivered via computers using words in the form of spoken or printed text and pictures such as illustrations, photos, animation or video.
- *Why*: e-learning courses are intended to help learners reach personal reading objectives or perform their jobs in a better way.

2.2.2 Computer Assisted Instruction (CAI)

CAI is a part of e-learning which refers to instruction or remediation presented on a computer. An analysis reviewing research studies on grade one to twelve students showed that CAI has a positive effect on reading achievement [35, 36]. Findings suggested that using computer applications to teach reading hold great promise as instructional tools. CAI is among the range of strategies being used to improve student performance in school subjects including reading.

When using technology to teach reading, there are five essential areas of reading that should be incorporated; phonemic skills, such as sound segmenting and blending, phonics skills, vocabulary, fluency, and comprehension [15]. These five essential reading areas are explained in detail in chapter 4. Setting these as minimum requirements will give readers a better chance for success. A good reading program should also enlarge vocabulary and improve word recognition. This is important to enable the reader to recognise words quicker and to improve their ability to express themselves verbally and in writing. Different reading techniques should be introduced to improve reading speed, fluency of eye movements and to reduce the duration of fixation and to improve the span of recognition (the amount of reading matter that can be correctly identified or perceived during a brief exposure).

Torgesen [37] states that well-designed computer assisted instruction and practice has a number of features that may be important for students with learning disabilities or struggling readers such as:

1. The ability to provide timely and useful feedback and error correction; this prevents a situation where a learner pursues an incorrect concept for some time before being corrected. This is what happens in a typical classroom because there is one teacher who has to attend to about 40 learners.
2. The ability to alter, or provide additional instructional sequences based on the student's learning rate [37]

3. The ability to tirelessly present systematic and explicit instruction and to repeat explanations as needed; this is one advantage of using a computer because unlike a teacher, it does not get tired but goes on and on as long as there is a power supply. In all our reading activities, the learner could listen to the instructions, words and sentences, which were part of the exercise, countless times.
4. The ability to set precise criteria for movement through an instructional sequence [37].
5. The ability to provide variety and incorporate motivational features and feedback; this can be achieved through the use of audio and visual (animated or video) content.
6. The ability to effectively multiply the amount of time the student has to practise their reading. This of course is only applicable if students have plenty of access to the computing resources.

The primary limitation of computers, of course, is that they are not yet as "intelligent" as a well trained, experienced teacher in adapting instruction to individual student needs [37]. For this reason, computer assisted instruction should not be used as the complete answer to the intervention needs of struggling readers. Computers may be a very useful supplement to intensive teacher-led instruction, but they should not be relied on to provide the only intervention that struggling readers receive [12]. Reading programs essentially do what a good teacher would do while at the same time reducing the workload on the teacher [35].

CAI programs also offer children the opportunity to be computer literate and to work in a highly interactive and entertaining environment in the form of animation, sound, video and instant feedback. Based on the degree of interaction between the student and the computer, there are several levels of CAI [33, 35]:

Drill and practice

The computer provides the student with exercises that reinforce the learning of skills that are taught in the classroom and gives immediate feedback on the correctness of the responses. This level is therefore a supplement to classroom instruction and is useful where the teacher cannot attend to each student individually. In comparison to traditional exercises, drill and practice on the computer can give more motivation to the students through the use of incentives like sound and animation.

Tutorial

This level provides more information about a subject and provides practice exercises. The computer therefore takes over actual instructional functions, that is, physical teacher functions. Records of the student's level of achievement are kept.

Dialogue

In this type, the student plays an active role interacting with the computer and giving instructions in the form of a computer language in order to structure the student's own curriculum. The computer provides information, exercises and feedback.

Simulation

Some lessons cannot be presented in the real situations, for example, medical students learning to operate on a person. The computer can simulate this for simpler understanding.

Education Game

These can include filling in the blanks, completing puzzles and problem solving games. The aim of these games is to help in improving learners' style of thinking.

Demonstration

This introduces the visual image to make students understand more easily. For example, the teacher can use a computer to demonstrate the orbital motion of the planets in the solar system.

Testing

We may use CAI in measuring learners' educational achievement. This may be done by creating user accounts for the learners as a way of identifying them and recording their learning achievements when they use the software or take an assessment test.

In this project, we elected to use CAI at two levels. Firstly, we are focused on drill and practice because our intention was to supplement the reading lessons children have in the classroom. Drill and practice is useful especially for word recognition and letter-sound recognition exercises. Secondly, we used the education game aspect especially where learners have to complete sentences and spell words while getting rewards for the correct answers. Games are vital tools in keeping learners motivated as they read. In designing the core engine of FundaWethu we used a slot-machine metaphor. A slot machine has wheels and each wheel can hold a primitive building block of language (letter, syllable, word, and phrase) therefore

giving FundaWethu flexibility; this is explained in detail in chapter 4. One of our aims when creating FundaWethu was to pursue an edutainment theme using multimedia. To do this we reviewed literature that gives guidelines on how to effectively use multimedia for learning and these are discussed in sections 2.4.

2.2.3 The benefits of CAI

There are generally several advantages of incorporating computers in reading instruction. Computer programs are interactive and can illustrate a concept through attractive animation, sound, and demonstration. They offer a different type of activity and a change of pace from teacher-led or group instruction [38].

CAI modules include a variety of learning modes; exercises, tutorials, and practice games. This comprehensive aggregate of technological, instructional and motivational features seem to affect the children's acquisition of reading skills at different levels [39], as shown in the following examples. According to Mioduser et al. [39], "*Forty-six pre-school children (aged 5-6), at high risk for learning disabilities, participated in the study. They were assigned to one of three study groups that received different treatments. Three dependent variables were defined, that is, children's phonological awareness, word recognition and letter recognition skills measured prior and after the treatment. Results clearly indicated that children at high risk who received the reading intervention program with computer materials significantly improved their phonological awareness, word recognition, and letter naming skills relative to their peers who received a reading intervention program with only printed materials and those who received no formal reading intervention program.*"

In order for learners to continue practising reading, they have to stay motivated. Firstly, computers can provide immediate individual feedback based on the student's performance. Secondly, properly arranged courses may be operated independently with computers, thus relieving teachers from some of the burden and giving students more opportunities to learn independently [33]. Finally, through presentations using different media, students' motivation to read may be strengthened [30]. G. Ayorkor Mills-Tettey et al. [40] outline experiments that were done with Project LISTEN's Reading Tutor in Ghana and Zambia. The Project LISTEN experiments showed improvement in the reading abilities of the children which further supports the crucial role that technology can play in literacy development.

Mastropieri [41] discusses a reading experiment done by Jones, Torgesen and Sexton in 1987 using a program called "Hint and Hunt". They found that CAI increases reading fluency and accuracy if it is used frequently, that is, daily practise. Thus we can conclude that CAI is a convenient tool for both learners and teachers; it can decrease the workload on teachers and improve reading skills in learners while they learn at their own pace.

2.3 Educational software design

There is considerable software that claims educational goals, but this software is designed for commercial purposes and often lacks a solid educational basis [42]. However, an educationally sound basis is not enough for the development of a good software product. Foundation phase children, especially in poor communities are reading learners rather than skilled computer users. The program should therefore have a very clear and easy to use structure [43]. In order to design software that will help achieve the learning goal, it is important to follow design criteria in terms of the software, the content and the user interface.

2.3.1 Age of the target group

In user-centred design, the design is driven by knowledge of the target users. The age range of the target users is one important factor that should be considered when designing software. At different ages, children's relation to interactive technologies varies, reflecting their changing interests, humour, characters, contexts and settings [44]. Researchers [44] have classified children into four stages of development, namely, *the dependency/exploratory stage (ages birth–2 years), the emerging-autonomy stage (ages 3–7), the rule/role stage (ages 8–12) and early and late adolescence (ages 13 and up)*. In this project, our target group is the emerging autonomy stage (ages 3-7) with a likely overlap into the rule/role stage because there are some children in this stage who are still struggling to read. In the emerging autonomy stage, children enjoy fantasy and magic [44]. Children of this age group are fairly self-centred, doing a lot of parallel play (we observed this in our usability study where learners sometimes argued because they wanted constant control of the mouse). They have a need for stimulation, love and safety, though they are developing a greater need for freedom [44]. The product or artefact for this target group should therefore be as simple as possible. Artefacts should be based on concepts that are not too abstract and are tuned to the not yet

fully developed reasoning skills of this age group. The meaning of onscreen buttons is mostly depicted using symbols and animations, with limited use of words and explanations.

Usability and fitness for purpose are crucial in designing for children. Two major concepts in this regard are [44]:

- Age-specific interaction styles, for example, how the menus are structured, the size of the on screen objects, fonts used, the suitability of input devices and
- The involvement of children in the design process. This happens via usability tests, which may possibly lead to artefact enhancement or transformation.

Compared to adults, children interact with technology mostly in relation to two activities: education/learning, and play. The more traditional Human Computer Interaction (HCI) considerations about usability and usefulness need to be extended and specialised with some consideration of how to create successful learning activities [44].

2.3.2 Software

In FundaWethu, the content is created by education specialists so we are working with the assumption that the educational basis of the software is sound. Our major concern was to therefore ensure that FundaWethu maintains the learners' interest time after time by fostering engagement and motivation [45]. In developing FundaWethu, one condition that we bore in mind was to create a product that would operate properly on the Information and Communications Technology (ICT) infrastructure available in the institutions where it is to be deployed, for example, dedicated graphics cards are not usually available in schools. (This was a setback in a related project we worked on in 2008 using Microsoft XNA, so FundaWethu deliberately targets more modest hardware.)

Another important factor in educational software is to incorporate a graduated challenge by initially providing a relatively easy learning curve. This allows learners to familiarise themselves with FundaWethu's interface and environment.

The interface should be intuitive with information and controls which enable the player to both understand what they need to do and to act without being distracted [45]. An intuitive interface contributes to ease of use which is very important for our target group (foundation phase learners).

Clear and immediate feedback is also an important requisite for educational software [46]. If the learner gives a correct answer, giving some sort of reward, for example, playing an audio file or access to a fun game, would be a good motivational tool for learners. If the answer is not correct, the program should show or give learners a clue on how to correctly answer the question.

The development of graphical user interfaces for educational software means that more and more children are controlling computers with a mouse. A considerable amount of research investigating children's use of a mouse has been done. For example, Joiner et al. [47] cite a research by King and Alloway which compared children's use of a keyboard, joystick and mouse and found that children of all ages were quicker and more accurate with the mouse. This implies that children could be most efficient using the mouse as an input device. Research by Segers and Verhoeven [43] showed that children were frequently found to have difficulties with the ‘‘drag and drop’’ procedure but we decided to try it in FundaWethu and see how it would be received. We used the mouse as our input device with the long-term goal that it could be developed to a tactile mode (for example, a touch screen) at a later stage. The touch screen provides more direct interaction than the intermediary mouse, and might therefore be a better input mechanism.

2.3.2.1 User interface

Multimedia user interfaces combine different media such as text, graphics, sound, and video to present information. Due to improvements in technology and decreases in costs, we are now in a position to design user interfaces that include multimedia. Since many educators, parents, and students believe that multimedia helps people to learn, one popular application of this technology is in the field of education.

In any learning situation, four basic factors should be considered when evaluating learning; the characteristics of the materials, the learner, the learning task, and the test of learning [48]. In this review of literature, we focused mainly on the materials factor because it encompasses what we are doing in designing FundaWethu. The other factors fall more into the domain of the education specialists who are in charge of the content of FundaWethu.

The characteristics of the learning materials can significantly affect learning. Learning material characteristics include the medium, physical structure, psychological structure,

conceptual difficulty, and sequence [48]. Researchers [46, 48] suggested the following ways to design the learning materials to improve learning.

2.3.2.2 Use the Medium that best communicates the Information

There is evidence that suggests that some media are better than others at communicating certain kinds of information [49]. For example, short term retention of a small amount of verbal information, is achieved better when that information is presented via the auditory medium compared to presentation via text [48]. For retaining information over longer periods of time, text seems to be better than sound for communicating verbal information. Also, if the learner's visual channel is already occupied, then it may be more appropriate to use audio verbal information than textual information [48]. This occurs, for example, when pictures and audio information are presented together. In the spelling exercises in FundaWethu for example, we present pictures and audio information together to assist the learner in learning to spell. In the word spotting exercise we present text together with audio information to help learners recognise words.

Pictures on the other hand seem to help people learn information more effectively than text [48]. For example, pictures of common objects are recalled and recognized better than their textual names. However the shortfall of pictures in terms of recall and recognition occurs when items are conceptually similar (for example, when pictures of various animals are presented the learner may be confused in trying to identify them). The pace at which the pictures are presented also affects recall and recognition.

To present motion-based information that changes continuously over time; animation or video appears to be best [46]. Animations are quite useful when teaching verbs, like running, because you can use an animated gif image that shows a running person. Children just starting to read have also been found to benefit from talking books with accompanying text and reinforcement activities [23].

From the discussion above, we can conclude that some media communicate specific kinds of information better than other media [43], thus when creating educational software, it is important to choose media that will communicate information effectively.

2.3.2.3 Multimedia should be Supportive, not Decorative

A great investment is typically made on animation and special effects, which can be very motivating but also distract the child from the educational task [43]. As a result, the information presented in one medium needs to support or relate to the information presented in the other medium, for example, the use of supportive pictures with audio information. Several studies show that adding closely related, supportive illustrations to text or auditory information (dual-coded information) improves learning performance by allowing learners to build cognitive connections between the verbal and pictorial information [50]. We used dual-coded information extensively in FundaWethu. We did this by using images to illustrate some text and audio information as well.

2.3.2.4 Present multimedia synchronously

There is strong support for the idea that verbal-pictorial information should be presented together [48]. Synchronising audio and animation or video results in creative problem solving and recognition compared to a situation audio precedes or follows the animation. An example could be watching a video that follows a recipe to cook a meal. Synchronising audio narration and video works better than watching the video first followed by the narration or vice versa. Information that is processed through both verbal and pictorial channels appears to be learned better than information that is processed through just the verbal channel or just the pictorial channel [39]. This is the reason why we chose to use both channels in FundaWethu to maximise learning chances for the foundation phase children.

2.3.2.5 Use elaborative media

There is also evidence that the media may encourage elaborative processing which helps to integrate the learning material with prior knowledge [43]. Elaborative processing often leads to improvements in learning performance [48]. Some media may encourage elaborative processing of information more than other media [51], for example, pictures may be more elaborative than text and text may also be more elaborative than audio media.

2.3.2.6 Make the user interface interactive

Many researchers strongly support this design principle [43]. Singhal [6] states that effective and successful reading programs are those that generate student participation, that is, allow the student to fully interact with the program both visually and in action (typing, clicking and

dragging). Interaction is mutual action between the learner, the learning system, and the learning material. An interactive user interface may allow learners to control, manipulate, and explore the material or periodically asks learners to answer questions that integrate the material [43]. Research [46] [48], shows that an interactive user interface has a significant positive effect on learning from multimedia because it encourages learners to elaboratively process the learning material. The interaction must be cognitively engaging rather than having continuous plain text or simple feedback like "correct" or "wrong". Feedback for example could be made more engaging by using various audio "beeps" for wrong answers and maybe "applause" for a correct one.

Therefore, to design a successful or effective reading tutor, it is advisable to incorporate the guidelines outlined in the discussion above. The list of design criteria mentioned above is not exhaustive or definitive. Table 4 presents another list of design criteria which were derived from a comprehensive literature review **[52].**

CURIOSITY, FANTASY AND PLAYER CONTROL	
Intrinsic motivation, enjoyable to play:	Engages player's curiosity, encourages fantasy, challenges the player, and puts the player in control of the gaming world. The design of the game itself provides motivation to play.
Educational content intrinsic to game play:	There is an integral and continuing relationship between educational content and fantasy or play aspects of the game.
Child control:	Puts children in a position to lead the game and set their own pace.
Free exploration:	Encourages curiosity, allowing for independent free-exploration of the game world and encouraging hidden secrets to be discovered.
Periodic saving of game state:	Allows players to save as desired or at regular intervals.
Multiple paths:	Provides more than one path through the game. Games should be non linear, allowing for multiple ways to win or solve problems.
Trial and error:	Encourages trial and error as one way to solve problems.
Reasonable solutions:	Reasonable solutions solve the problems presented. Winning is based on knowledge, not chance.
Incremental tasks:	Large tasks are accomplished in steps.

Realistic world representation:	The world is realistically simulated.
Real-world contextualization:	Learning content is contextualized within real-world situations.
Personalization:	Allows users to personalize game characters and customize graphs, backgrounds, and objects.
Provision of choices:	Provides choices among various game modes and learning themes.
Avoid repetition:	Avoids repetition. Avoids drill and practice.
Random elements:	Provides random elements of surprise.
No loss of points:	Points are not lost for wrong answers or failures.
CHALLENGE	
Performance criteria:	Performance criteria are clearly defined.
Constant challenge:	Difficulty consistently and appropriately exceeds the player's level of understanding.
Expanding complexity:	Expands in complexity as skills are mastered. Provides game levels for a wide range of abilities.
Monitor performance:	Monitors player's performance, increasing and reducing difficulty to provide continuous challenge.
Display progress:	Clearly indicates progress. Players are able to evaluate their progress at any time.
Real-time hints and instruction:	Provides hints and real-time instruction as needed to scaffold the player.
Induce flow state:	Helps players find their flow state, the point at which challenge and ability to overcome the challenge are perfectly matched.
SOCIALIZATION	
Collaboration:	Provides opportunity for collaborative play.
Competition:	Provides opportunity for competition among players.
Multiple winners:	Allows multiple players to reach the highest level.
PEDAGOGY	

Age appropriate:	Clearly states the target age group and is designed appropriately for that group.
Learning activities:	Recommends learning activities to conduct in conjunction with the game.
Learning objectives:	Clearly states educational objectives and educational philosophy.
Opportunity for adult mediation:	Incorporates provisions for adult mediation. Acknowledges the role of a teacher or parent.
Clear game-play instruction:	Provides clear direction, enabling players to focus on content rather than the rules governing game play.
Tutorial levels:	Offers tutorial levels that allow players to learn by doing rather than reading the manual.
TECHNOLOGY	
Mainstream technologies:	Runs on technologies available and affordable to schools and the general public.
Licensing:	Provides attractive licensing agreements for schools.
Usability:	Provides an intuitive user interface.
YOUNG CHILDREN, SPECIAL-NEEDS CHILDREN	
Spoken directions:	Provides spoken directions. Written directions may accompany spoken directions.
Uncluttered design:	Graphics and gaming screens are not overly cluttered.
Play for the sake of play:	Playing the game is in itself a meaningful activity.
Visible transformations:	Child actions impact the software, changing objects and colours and producing sound effects through their interaction.
Simple input/output:	Intricate keyboard or mouse control is not required. Even banging on the keyboard or aimless movements of the mouse produce visible transformations.
Sequential increase in challenge:	As the child learns, the game becomes more challenging. Sequential steps may be necessary to progress where only one button push was previously required
Familiarity and repetition:	Game activities are enjoyable to repeat. Aspects of the game are memorable, such as main characters, theme songs, and catch phrases.
Relate to daily life:	Objects and sounds are taken from daily life. They are things that children can easily recognize.

After play:	Inspires children's play after the game, i.e., even when the computer game is off.

Table 4: Design criteria for educational, edutainment and developmentally beneficial computer games [52]

In FundaWethu, we met some of the criteria listed in Table 4 specifically in the young children/special needs children section. We chose to use written instructions accompanied by spoken instructions for all the reading activities. We used a simple and uncluttered interface (Figure 13). We incorporated visible transformations through the use of a drag-and-drop interaction in the sentence-completion exercise and the jumbled story exercise. The children could see the impact of their actions when they dragged a word and it was virtually lifted and moved to the blank space. We used simple input by means of the mouse with no keyboard involvement. Children thrive on sequential increase in challenge [52] and we incorporated this into our lessons by categorising them in varying levels of difficulty. We met the familiarity and repetition criteria by giving children the option to repeat each lesson, we made use of catchy theme music that they enjoyed and the audio files were recorded by their teacher which gave them a familiar voice. Letting the teachers create the lessons helped to give the children lessons that they related to in daily life because the teacher had a better knowledge and understanding of the children and their backgrounds.

Summary

In this chapter we explored three main themes. Firstly, we discussed the research problem and a potential solution which is, building a tool that could be helpful in alleviating the problem. Secondly, we discussed the debatable role of technology in education citing various researchers who have shown that CAI can improve learning including reading. We also discussed the ways in which technology is used in education, that is, e-learning and CAI. Thirdly, we explored principles on how to create educational software that will foster learning and also be entertaining. Some of these principles will guide or influence our implementation decisions that are discussed more fully in Chapter 4.

CHAPTER 3: DESIGN-BASED RESEARCH METHODOLOGY

Design-Based Research is an iterative methodology, particularly applicable in educational and learning studies where an artefact (for example, FundaWethu) is being built, that employs repeated trials and feedback to refine and adapt the artefact, and to adjust the study as it progresses. It is founded on collaborative work between researchers and practitioners in the real world. Our approach to building FundaWethu uses the Design-Based Research Methodology. We define and discuss this approach, with some comment on its strengths and weaknesses. We also compare this methodology with other more "traditional" research methods.

3.1 Definition

Wang and Hannafin [53] defined design-based research (DBR) as follows:

"a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories."

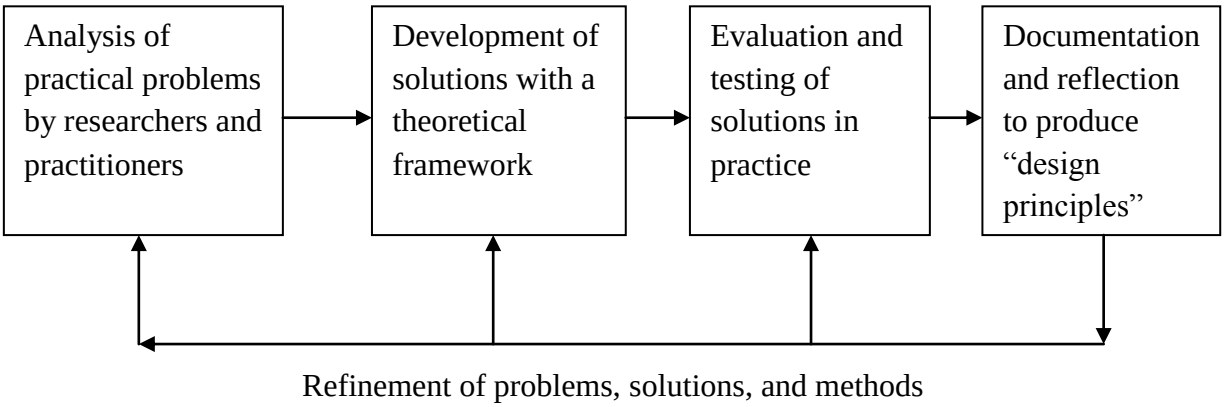

Figure 1: Design-Based research diagram

The design-based research paradigm, advanced initially by Ann Brown [54] and Allan Collins [[55] as "design experiments", affirms the existence of relationships between design and engineering and is both scientific and educational [56]. Design-based research is suitable

for both research and design of technology-enhanced learning environments (TELEs) because it integrates the design of the artefacts and research processes [57]. The existence and nature of an artefact distinguishes design-based research from other endeavours, such as action research [58]. The objective of a widely usable artefact (in other similar contexts) is one of the fundamental requirements of design-based research but it is not possible to design a "perfect" or "absolutely correct" artefact because the intended users do not have the same competence, intention or motivation as designers [59]. We minimised this drawback in FundaWethu by introducing flexibility using the lesson authoring tool and creating a versatile delivery engine that can handle a diverse range of the primitive building blocks of language. This makes it possible to tailor lessons to an individual, tailor the lesson around a choice of letters, prefixes, syllables, phonemes, words, phrases or sentences, and deliver them in any indigenous South African language.

Many researchers have been involved in endeavours that combine designing an artefact and educational research. The focus of each endeavour divides this broad field (design and research) into smaller segments. Juuti and Lavonen [58] reviewed several groups of research that show the different facets of this type of research:

1. In design experiments (pioneered by Ann Brown [54]) emphasis is placed on the comparison of several versions of the designed artefact. One example of this is a project that we carried out for my honours' studies where we created "*3D Noughts and Crosses*" using Microsoft XNA. We went through a number of iterations in order to come up with the final versions of the game. The first version of the game consisted of 27 cubes arranged in a 3 x 3 matrix. Each player could place a 3-D model (e.g. a duck) into a position in the game, and getting 3 similar marks in a row was a win. In this version the computer almost always won the game and we thought this would eventually discourage the children from playing it. We thus created the second version which worked the same way except that the middle cube in the matrix was omitted to make it easier for the children to compete.
2. In developmental research the focus is on the analysis of an artefact or a successful design process in order to come up with theories on how to design an artefact that will result in a better outcome. To do this many examples and case studies of current practice are reviewed.

3. In user-design research the emphasis is on the role of the user and focuses on software design in order to meet the needs of the user, In other words, the user's opinions, experience and needs shape the design of the artefact.
4. In design research, researchers focus on the design process, the features of an artefact and resultant educational knowledge (theory) that is developed. It also serves as a way of improving researchers' understanding of the learning practice [58].
5. Design-based research on the other hand encompasses the features of design research, but also emphasises the long-running projects in single settings, and provides compelling comparisons of innovations and collaboration between teachers and researches. This is the approach that we used in this project and we compared it to Project LISTEN that was carried out in Zambia [40].

Research endeavours that involve design usually consist of three parties [58]:

- A designer who can also be the researcher as depicted in this project,
- A practitioner or someone who has vast knowledge in the area to be researched, for example, a teacher, and
- An artefact, for example, reading software.

The role of the parties varies depending on the endeavour but it is important that there be a good relationship and interaction between the designer and the practitioner in order for the project to be a success. Juuti and Lavonen [58] also proposed that the following three features determine design-based research:

- The design process is iterative;
- The objective of the research is to develop an artefact that will help teachers and learners to act (teach and learn) more intelligently;
- Design-based research produces novel knowledge about the science of teaching and learning. All three features together constitute an endeavour that is called design-based research.

A design-based research project goes through different phases from inception to completion. The European committee for standardization has published a standard for human-centred design processes for interactive systems [60]. This standard can also serve as a guideline for design-based research and it emphasises four phases:

- **To understand and specify the contexts of use** [60]. This is when the researcher does informative exploration of the context that they intend to work in. At this stage, we consulted the teachers, principal and some people from the education department who were running a literacy program at the school. It was from this, that we found out there was an after school reading program at the school which was aimed at helping struggling readers in the foundation phase. There was still need for more volunteers in the program and as a result the teachers welcomed the use of CAI to help some of the struggling readers. We found out that the learners were reading in a bilingual context which was useful information to consider in the design of FundaWethu.
- **To specify the user and organizational requirements** [60]. From the informed exploration, the researcher filters information that is used to determine user and organisational requirements. In this phase we assessed the computer lab which we intended to use for the usability test. Only one out of about ten computers was working, so we brought in four of the computers for repair. A reading test was done on the children and the results were used to group them according to reading levels. Since the teachers had better knowledge of the children's performance, they were pivotal in determining the approaches that could be used to teach the children. For example, they talked about using the syllabic approach when teaching isiXhosa. This approach emphasises getting the children to know and understand how words are built using syllables and they can in turn be broken down into syllables. Because the children were learning in a bilingual context (isiXhosa and English), it was important to incorporate language diversity into FundaWethu. A total of ten children were assigned to the CAI group and we chose a meeting time and day. We brought the principal and the rest of the staff up to speed on the reason for the project and its potential benefits for the children.
- **To produce design solutions** [60]. There was an overlap with the previous phase because while we determined user and organisational requirements, we were building a prototype of FundaWethu. Getting an early start meant that we could get ample time to refine FundaWethu until we got an adequate system for the learners.
- **To evaluate the design against the requirements** [60]. This phase also overlapped with the previous one because as we evaluated FundaWethu, we used the feedback to refine it. We did the evaluation using a usability study which was carried out over ten weeks. In this study we observed the learners' interaction with FundaWethu, taking note of the difficulties they had. We also ran interviews with the children and their

teacher in order to get more information that would be useful in determining if FundaWethu had met the user requirements.

3.2 Main characteristics of design-based research

Wang and Hannafin [53] proposed five basic characteristics of design-based research: Pragmatic; Grounded; Interactive, iterative and flexible; Integrative; and Contextual. Cobb et al. [61] and Shavelson et al. [62] on the other hand proposed 7 basic characteristics of design-based research: Iterative; Process focused; Interventionist; Collaborative; Multileveled; Utility oriented; Theory driven. The summary of the characteristics of design-based research according to Wang and Hannafin is as follows:

Pragmatic; its goals are solving current real-world problems by designing and enacting interventions as well as extending theories and refining design principles [63]. This goes hand in hand with the **interventionist** characteristic suggested by Cobb et al. and Shavelson et al.. In our project, the problem is poor literacy levels which are a result of lack of resources, that is, human, material and financial. Our niche population is foundation phase children who learn in a bilingual context, that is, isiXhosa and English. Therefore we saw an opportunity to introduce literacy software that is multilingual and flexible, in terms of content, which will help in literacy development.

Grounded; design-based research is grounded in both theory and the real-world context [53]. It has a **theory driven** nature because it tests and advances theory through the design-analysis-redesign of instructional activities and artefacts [62]. In addition, design-based research is conducted in real-world settings complete with the complexities, dynamics and limitations of real practice in daily life. Design-based research, by virtue of being conducted in a real-world context in **collaboration** with practitioners, is much more likely to lead to an effective application [58, 64, 65].

Interactive, iterative and flexible*;* design-based research requires interactive collaboration among researchers and practitioners. This is a way of optimising the research so that it has a better chance of effecting a change in the real world situation [58]. Design-based research is also iterative because theories and interventions tend to be continuously developed and refined through the design-analysis-evaluation-redesign cycle. This ongoing iterative nature

of the design process also allows greater flexibility than do traditional experimental approaches.

Integrative; because researchers need to integrate a variety of research methods and approaches from both qualitative and quantitative research paradigms, depending on the needs of the research.

Contextualized; because research results are "*connected with both the design process through which results are generated and the setting where the research is conducted*" [53].

One important habit that design-based researchers need to have is keeping detailed records during the design research process concerning how the design outcomes have worked or have not worked, how the artefact has been improved, and what kind of changes have been made. This ensures that other researchers interested in the findings can examine them and possibly use them for other research.

3.3 The designed artefact and the teacher

Because design-based research is pragmatic, the role of the designed artefact is to help a teacher to teach more intelligently and effectively [58]. This means that the artefact does not replace classroom work but supplements it. In order to use the artefact successfully, a teacher should understand, agree with and personalise the artefact. At the start of this project we consulted the teachers from our target school on what we could do to help in their literacy program. Involving them from the start was important in helping them understand the aim of the intervention. We found this to be beneficial in the countless times we visited the school to work with the children because the participants and their teacher were keen and the laboratory was always clean and ready every Tuesday afternoon. Based on the experience of Lavonen et al. [66] on the designing and teacher adoption process, no matter how brilliant the artefact is, if teachers do not understand what it is aiming to achieve, they will not adopt it.

When designing, it is important to consider the teachers' competence, beliefs, intentions and attitudes towards the artefact and it intended use [58]. When it came to usability testing of FundaWethu, we worked with one Grade 2 teacher and a group of ten learners. Although the teacher's competence with computers was very little, her attitude towards CAI was positive because she believed it was an exciting way of teaching reading that could motivate children

to read better. We gave the teacher some training on using the computer and FundaWethu in particular.

3.4 Design-based research outcomes

The context is one of the key components of design-based research. When doing design-based research, researchers should acknowledge the difficulty in educational research of ensuring control [67]. This is because unlike a traditional experiment, there is no control and experiment group which is used in order to isolate the variables that lead to success or vice versa. DBR is done in a natural context (for example a classroom or a computer room with a number of people, noise from outside and from the participants, people moving in and out of the room, the different moods of the teacher and children depending on the day they had etc) with a combination of dynamic variables that may change daily. Because DBR is carried out in a specific context, the results cannot be generalized to cover every area of education. Instead they can only be applied to a similar context/set up. Design-based research outcomes are therefore a culmination of the interaction between the designed artefact and dynamic variables (human psychology, personal histories or experiences, and local contexts) [67]. As a result, when embarking on design-based research projects, researchers should commit to the fact that the research may not go as planned. "*The intervention is the outcome in an important sense.*" [63]

Unlike experimental research, design-based research involves collaboration between researchers and practitioners (for example teachers) therefore blurring the "objective" researcher–participant distinction [67]. Because of the dynamic variables involved in design-based research, the intervention may change as the research progresses. Since the enacted intervention is regarded as the outcome of design-based research, the researcher has to document what has been designed, the reasons for designing that way and the changing understanding of both implementers and researchers of how the intervention embodies or does not embody the hypothesis that is being tested [67]. To reach our goal in this project, we asked the question:

> *Can we build a cost-effective, fun, language-adaptive and flexible lesson authoring, and delivery platform that could assist teachers, researchers and learners involved in bilingual foundation phase teaching?*

3.5 Differences between DBR and other research approaches

Because design-based research lacks the control that is found in traditional research methods, it receives sizeable criticism in the academic research world. In this section we explore the differences between DBR and other research approaches and the ways in which the perceived "weaknesses" are actually its strength in the educational field.

3.5.1 Design- based research and Laboratory experimental research

Allan Collins [54], one of the pioneers of design-based research, compared the differences between DBR and laboratory experiments in the educational field. Design-based research deals with real world situations (natural settings without controlled variables) that have dynamic variables (limitations and complexities) while laboratory experiments are conducted in a controlled environment with limited interruption from external variables [54]. Because of this control, laboratory experiments tend to be fixed, in other words, the procedure to follow from the start to the end of the experiment is set. Design-based research on the other hand evolves as the research progresses by using iterative and flexible revisions to come up with a solution that will meet the requirements in that context [68]. The motivation for carrying out design-based research in natural settings is that the intervention being carried out is expected to work in the same settings. In contrast to laboratory experiments, design-based research involves social interactions with the practitioners and participants while laboratory experiments tend to isolate participants and prevent interaction with the outside world [68].

3.5.2 Design-based research and Design

Edelson [69] proposed four features that distinguish design research from design.

- Design-based research is research-driven, meaning that it makes use of prior research. In our case, we based our project on previous research that showed that South African foundation phase learners had low reading levels [1] and that CAI could improve their results [40]. The guidelines that we followed in designing FundaWethu were a result of previous research on designing educational software [46, 48, 52]. Design-based research has clear research goals, produces empirical results and it is theory–based [69]. Our goal in this research was to create adequate reading software that would be flexible enough to allow authoring content in indigenous South African languages.

The observations we made when learners were using FundaWethu were valuable in refining the software so that it could meet the needs of the learners.

- Design-based research produces a design narrative (documentation of the design process). This documentation throughout design-based research helps data analysis, especially retrospective analysis. During the design process we documented every change that we made and the reasons for the change and we noticed that this came in handy in the analysis which is described in detail in chapter 6. We also video recorded most of the sessions we had with the learners. These were useful in retrospective analysis for asserting the behavioural traits of the learners when they were using FundaWethu. This is a reliable way of determining the user satisfaction of children [70].
- Formative evaluation is an essential part of design-based research. This is where the researchers identify the problems on the ground and the limitations, and make informed decisions on the ideal design goals. This allows designers to tailor the design to the needs of the targeted users (personalised learning) [71].
- The ultimate goal of research is generalization of the results in other applicable contexts. The documentation generated during the design process could be useful when one wants to design an intervention for a similar situation [69].

3.5.3 Design- based research and Action Research

Like action research, design-based research identifies real world problems and subsequent actions to improve the situation [68]. Both research methods also involve practitioners such as teachers in the research process. The difference between design-based research and action research is with regard to the role of researchers and practitioners in the research process. In design-based research, researchers usually take the initiative in the research process as both researchers and designers [53]. In action research, however, it is usually the practitioners who initiate the research and then the researchers help facilitate the research process.

3.6 DBR in this project

As we have seen in the previous sections, DBR is iterative and therefore flexible but it has several challenges. In this project we set out to build a tool that could help readers in the foundation phase who are learning to read in a bilingual setting. DBR was active at three

levels; the software, the content (that is, lessons) and the intervention itself. Design-based research deconstructs the presumed integrity that the research should not be contaminated by the external influence of the research [5]. Researchers in design-based research processes collaborate intimately with participants to produce an intervention that will impact the educational practices they are exploring.

In FundaWethu, the design-based research paradigm was evident at three distinct levels:

- The construction of the hardware and software artefact (the "platform") itself was iterative, process focused, and utility oriented. Process focused means that it seeks to trace both an individual's and group's learning and the impact of instructional artefacts on that learning. The construction was utility oriented in the sense that it focused on improving the effectiveness of instructional tools to support learning. We built a rapid prototype of FundaWethu and worked with a number of teachers and learners to improve the software over a number of iterations. The design-delivery-redesign cycles are explained in more detail in chapter 4.
- The lesson construction also followed an iterative approach. With every session, we were able to change the media files (sound and pictures). Working together with a teacher ensured that we kept up to date with the curriculum because we could create new lessons with the new syllables or phonemes that the children were learning in class. As the lessons were developed and delivered, we got feedback that reflectively allowed us to enhance the lessons or ask different research questions of interest. We in turn fed back new requirements into the platform design process.
- The experiments/usability study with the children also followed an iterative and process-focused model. Our aim was to find the most effective way to use FundaWethu while maintaining the learners' motivation. Initially, we planned to take the children through all activities doing one per day. This did not work well because we observed the children quickly got bored with the monotony. So we decided to changed the sessions so that we could do two activities per session, for example, word recognition and flash card reading or spelling and sentence completion. This variety kept the children more interested and focused because they looked forward to doing the second activity. We also introduced group chats where the learners talked about the new words they had learnt and what they enjoyed for that session. Upon the teacher's suggestion to kill two birds with one stone, we set ten minutes towards the end of each session for children to write five new words that they had learnt. In this

way they could practise their writing. This kind of flexibility offered by DBR improves the chances of creating an artefact that will be effective in the specified context.

Our goal, as researchers engaged in doing design work, is to directly impact practice while advancing theory that will be of use to others. Hoadley et al. [63] argue that design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice. Design is very important in the creation of tools that foster learning, creating usable knowledge on learning and teaching in complex settings [63].

3.7 The benefits of DBR

Design-based research has several benefits and we will discuss some of them below.

3.7.1 Practical contribution

Design-based research is usually problem-driven, that is, the existence of a problem necessitates the research. By addressing the problem, researchers seek to change and improve educational practice and opportunity [68]. Design-based research produces results that consider the role of social context (a child who is exposed to reading material from a tender age has a better chance of becoming a good reader [2]. A child who has not been exposed to reading beforehand is thrown into the deep end when they start school and have to learn from the basics). Considering the social context therefore gives interventions a better potential for influencing educational practice [72]. Design-based research also produces artefacts and programs that can be adopted elsewhere.

3.7.2 Better ties between theory and practice

Due to the very close interaction between practitioners and researchers, design-based research produces well-designed interventions (materials, artefacts, and software) that are valuable in the educational field [68]. Practitioners provide the theory that is essential in producing results that will make a difference in the real life problem at hand.

3.7.3 Offers a useful methodological toolkit

To those researchers committed to understanding variables that determine learning within natural contexts, DBR offers a useful methodological toolkit [68]. Design-based research is not a fixed approach but it is an integration of approaches that evolve as the research progresses [61]. The goal is to produce new theories, artefacts, and practices that account for and potentially impact learning and teaching in natural settings [61].

3.8 Critical aspects of DBR

3.8.1 Absence of standards to identify potentially useful interventions

Finding time for research in classroom settings is always challenging, and DBR tends to be time consuming because of its iterative nature. Because of time constraints, time management in this kind of research should be done well in order to obtain useful results. In this project, we fit into this limited time frame by becoming part of the after-school reading programme and meeting the learners once per week. As time consuming as DBR is, there is no set standard to determine whether an intervention will yield fruits [64]. This is because DBR is designed in natural settings with unpredictable variables. For this reason, Dede [73] distinguishes the evaluation of the designed artefact from the conditions of its success. One of the unforeseen circumstances we had to deal with in this project was the civil servants' strike which put our work on hold for nearly a month. This is an example of a factor that affects the conditions of success of an intervention.

3.8.2 Excessive data and data analysis with little results

Brown [54] expressed concern over data selection as a possible limitation of design-based research. Due to the iterative nature of DBR, a lot of repeated data may be obtained through interviews, video recording and other means of data collection [54]. We noticed this in the video recordings of our sessions were our observations were basically "the same" every week. The learners would have initial difficulty when we introduced a new activity but after about twenty minutes, they got the hang of how it works and relaxed into enjoying their reading. The excess data usually requires a lot of effort when analyzing although the outcomes might only have tiny contributions to educational knowledge. For example, we had

4 hours of video recordings of the sessions with the learners. To do retrospective analysis we had to watch these to come up with observations that were more or less the same for each session. As a result, the trap of too little contribution and too much method is one into which DBR can easily fall [68].

3.8.3 Difficult to make generalizations across participants

The nature of design-based research in which adjustments can continually be made in the implementation of an instructional intervention makes it difficult to know the combination of features of the intervention that actually contribute to its success [68]. Generalizability refers to the extent to which the account of a particular situation or population can be extended to other persons, times or settings than those directly studied [74]. The fact that DBR can use both qualitative and quantitative methods and that it has a highly contextualized research agenda makes generalizability challenging.

3.9 Challenges of doing DBR

Although DBR is gaining ground in the field of education and is seen by many as a powerful research paradigm to improve educational settings, it comes with several challenges which need to be carefully considered by anyone who is interested in using DBR as a methodology in research [63]. This section outlines several issues as addressed by the Design-Based Research Collective (DBRC) [63] and some other practical challenges to DBR.

3.9.1 Credibility of data

Objectivity, reliability and validity are traditional criteria for ensuring the credibility of research data [68]. It is especially true for scientific and experimental studies. Objectivity can be interpreted in two aspects; neutrality and avoiding subjective interpretations of data [63]. This traditional view of credibility is difficult to apply to design-based research because the involvement of researchers in the research context and their interaction with participants is one of the distinguishing characteristics of design-based research. This involvement makes objectivity and neutrality challenging as it can bring about the Hawthorne Effect (participants react according to the researchers' expectations).

To deal with this challenge the DBRC [63] suggested that to promote objectivity, design-based researchers need to regularly shift between the roles of advocate and critic to eliminate bias and subjectivity. Triangulated data collection methods (collecting data from various sources, that is, both learners and teachers using direct observation and surveys) should be used to document the processes of enactment; this improves reliability and validity of the results. The validity of design-based research is determined by the ties between theory, design and practice. This is strengthened over time through collaborative partnership and iterations of the design process [63].

3.9.3 Collaborative partnership

A typical design-based research project is time consuming and may take years to complete. In addition, design-based research draws from multi-disciplinary expertise, as Sandoval and Bell [75] stated: "*On the research side…, design-based researchers draw from multiple disciplines, including developmental psychology, cognitive science, learning sciences, anthropology, and sociology. On the design side…, researchers draw from the fields of computer science, curriculum theory, instructional design and teacher education…*" Thus, it is important that design-based researchers maintain a good collaborative partnership with the various stakeholders because this influences the success of the intervention.

In order to maintain this partnership, researchers should have a good understanding of the social, cultural, and political dynamics in the research context. This is usually done in the informed exploration phase of the research. For example, in a situation where teachers are computer illiterate, patience and willingness when training the teachers goes a long way in building a good relationship.

3.9.4 Sustainability

Another challenge of design-based research is sustainability. Brown [54] stated that many new innovations are eventually abandoned by teachers due to a lack of support from the researchers. Therefore, it is very important that the practitioners "own" the designed innovations so that they stay motivated to maintain, or even improve the innovations in the long run.

One way to achieve sustainability is to bring teachers in as co-designers or co-researchers [68]. We did this by bringing in teachers as consultants from the start and giving them a tool that allowed them to create lessons for the learners. The benefits of this are:

- Teachers will be more committed to using the designed innovations because they took part in their creation.
- Teachers will develop essential knowledge and skills to deal with any changes without the need for external support. As the year progresses, more ground is covered in the curriculum, the lesson authoring tool allows teachers (without external support) to update the lessons in FundaWethu to keep up with the curriculum.
- Teachers will be more likely to appreciate the value of design-based research as a research method that works in the educational field, instead of merely adopting the designed artefact.

Another way to facilitate sustainability is establishing learning communities of teachers [68]. In this way, teachers can exchange ideas and learn from each other's experience. Peer teaching can be a powerful means for teachers to quickly learn new instructional strategies and products, as well as create a sense of ownership that motivates teachers to keep using the designed innovations [68].

Summary

In this chapter we defined design-based research and looked at its characteristics. We explored the different phases of design-based research and how they applied to our project. We made comparisons of design-based research and more traditional research approaches and finally we discussed the benefits, criticisms and challenges of carrying out a design-based research project.

CHAPTER 4: SOFTWARE DESIGN PROCESS

The aim of this project was to build a cost-effective, fun, language-adaptive and flexible lesson authoring and delivery platform that could assist teachers, researchers and learners involved in bilingual foundation phase teaching. Because our project was problem-driven; we took on a user-centred design process [43], to build a platform that would meet the requirements of our users (Figure 2).

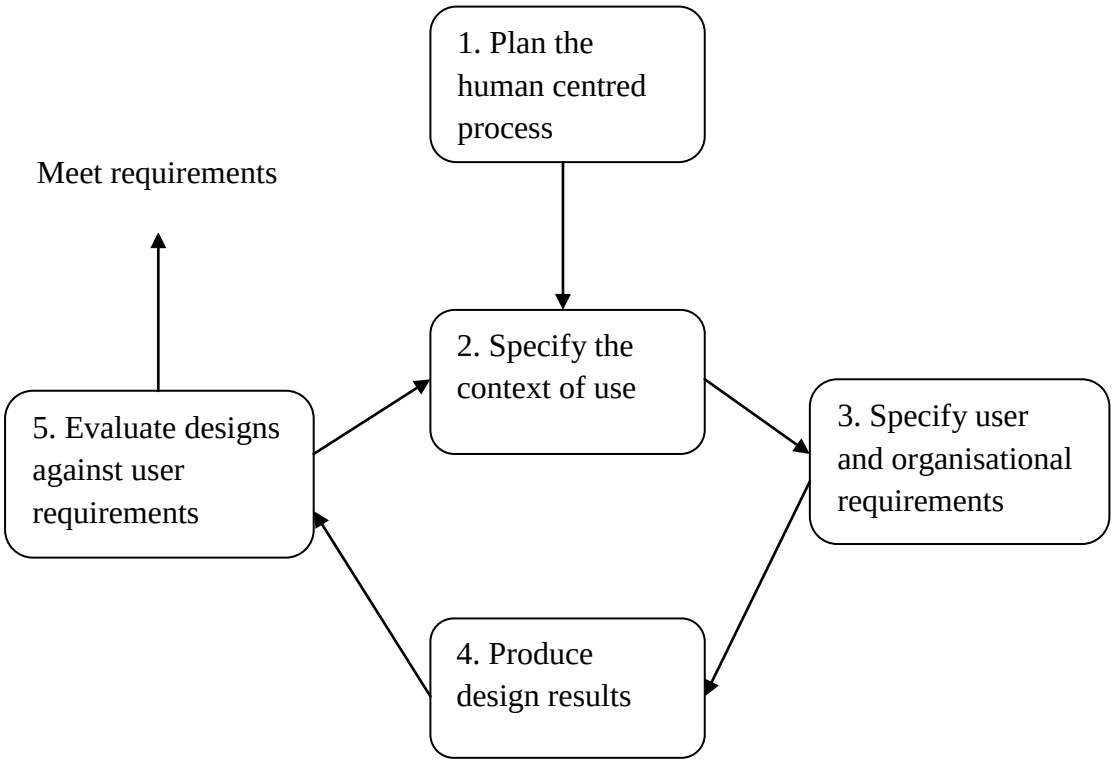

Figure 2: User-centred design [43]

Working in collaboration with practitioners allowed us to hand off the burden of ensuring that the software is educationally sound. This allowed us to concentrate more on designing good quality software (Figure 3) that would be adequate for our specified conditions (working with struggling readers in the foundation phase of education who are learning in bilingual conditions with little or no access to computers). Quality is characterised in terms of the ISO/IEC FCD 9126-1 definitions [43, 48] below:

· *Functionality:* the capability of the software to provide functions which meet stated and implied needs when the software is used under specified conditions.

· *Reliability:* the capability of the software to maintain its level of performance when used under specified conditions.

· *Usability:* the capability of the software to be understood, learned, used and liked by the user, when used under specified conditions.

· *Efficiency:* the capability of the software to provide the required performance, relative to the amount of resources used, under stated conditions.

· *Maintainability:* the capability of the software to be modified. Modifications may include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications.

· *Portability:* the capability of software to be transferred from one environment to another.

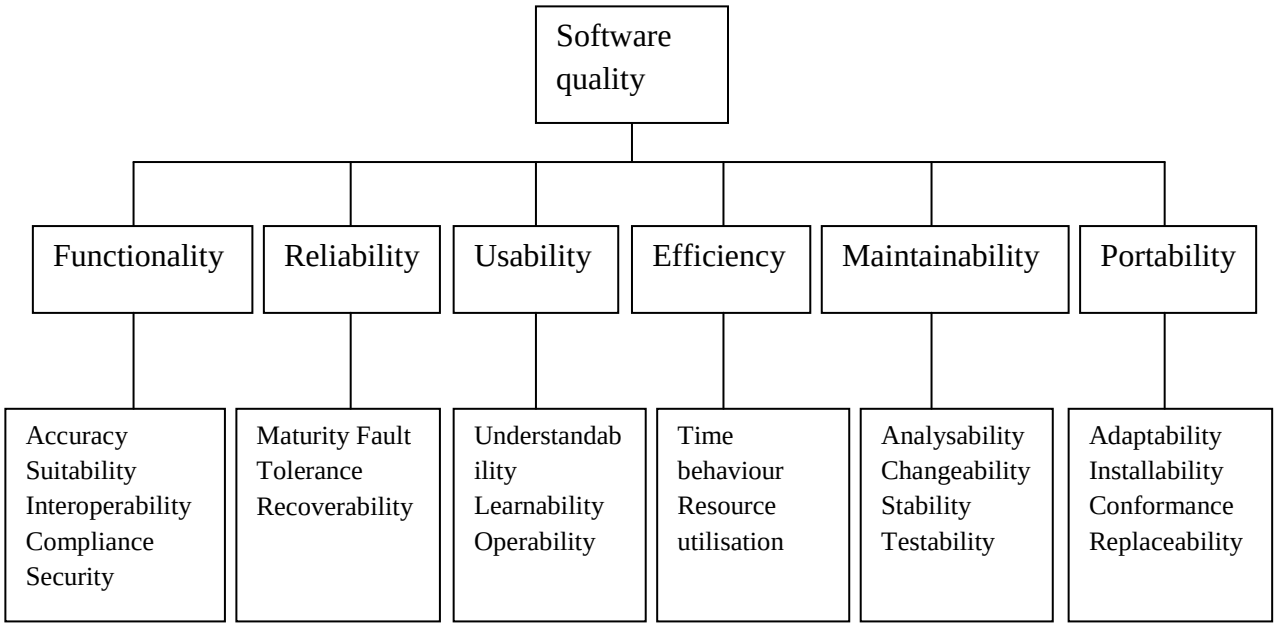

Figure 3: Software quality characteristics [43, 48]

Because our project was small and for a specific setting, we concentrated only on the first three characteristics, that is, functionality, reliability and usability, because they were in line with our goal of creating adequate software for our target users.

4.1 Design considerations

4.1.1 Initial prototype

DBR specifies a design-evaluation-redesign cycle through which an artefact is refined in order to work effectively in that particular context. This allowed us to go through a number of iterations in the software development of FundaWethu.

Our first reading activities would be "fill-in-the-blanks" type problems, where we would have to pick the correct solution from some multiple-choice alternatives. We adopted the design metaphor of a Vegas-style slot machine with a wheel representing each of the blank slots, and the multiple-choice alternatives available on the facets of the wheel. We envisaged eventually having animated rotating wheels which the user could stop to make their selection. This metaphor dictated our initial design of our class hierarchy and lessons. As we shall see later in this chapter, although we never pursued the slot machine metaphor in the user interface, it is still the organizing metaphor in our class hierarchy.

In the first prototype we created lessons using plain text files (Figure 6) and the user interface (Figure 7) consisted of list boxes on which letter choices were displayed. The slot-machine wheels were represented on the GUI by mush simpler list boxes, but it still allowed us to construct the lessons and have the user make the choices.

This introduced flexibility because it allows us to seamlessly create reading puzzles with missing words on the wheels, or spelling puzzles with missing letters on the wheels, or phoneme based puzzles with missing syllables like *pha*/*tsha*, or it can be used for sentences with missing words on the wheels. So our core engine can handle a variety of "primitive building blocks of language" – these can be characters, phonemes, syllables, words, phrases or sentences. This flexibility is especially important for reading in isiXhosa which is an agglutinative language (languages in which most words are formed by joining morphemes together) featuring an array of prefixes and suffixes that are attached to root words. Verbs are modified by affixes that mark subject, object, tense, aspect, and mood, for example, **um**ntwana, **aba**ntwana or **in**doda, **am**adoda.

After putting the initial prototype together, we started exploring ways of refining it to make it more functional, reliable and usable. A well designed reading program should target five

areas of reading which include phonemic skills, phonics skills, vocabulary, fluency, and comprehension [15]. There is a difference between phonemic and phonics skills. A phoneme is a speech sound. It is the smallest unit of spoken language and has no inherent meaning [76]. Phonemic awareness is the ability to hear and manipulate the sounds in spoken words and the understanding that spoken words and syllables are made up of sequences of speech sounds [76]. Phonemic skills include segmentation (separating words into individual phonemes) and blending (putting together individual sounds to make up a word). Phonemic awareness is auditory and it is essential to learning to read in an alphabetic writing system, because letters represent sounds or phonemes. Phonics skills on the other hand encompass the ability to map sounds to their corresponding letters [76]. Without phonemic awareness, phonics makes little sense.

The initial lesson structure was too restrictive when trying to expand the activities to include all five areas of reading. For example, when doing the sentence completion exercise, the list boxes represented our wheels (missing words) so we had to add more controls (labels) to hold the rest of the sentence (Figure 4). This setup took us away from the "normal" sentences (Figure 5) that have a dash to represent a missing word. The initial user interface also made it difficult to incorporate a drag and drop interaction mode. As a result we went back to the drawing board and decided to change the lesson format and the user interface. But our metaphor of the slot machine was still firmly embedded in the data structures and the program code, even if it no longer had the visual appearance of a slot machine.

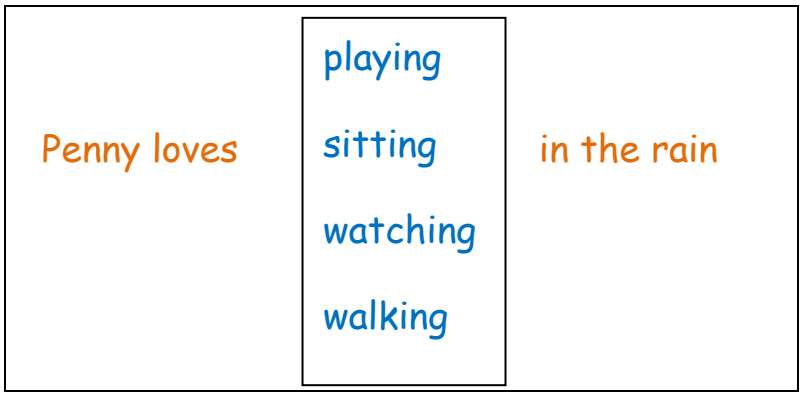

Figure 4: Scenario 1 with the initial prototype that used labels and list boxes to display sentences for the sentence completion exercise

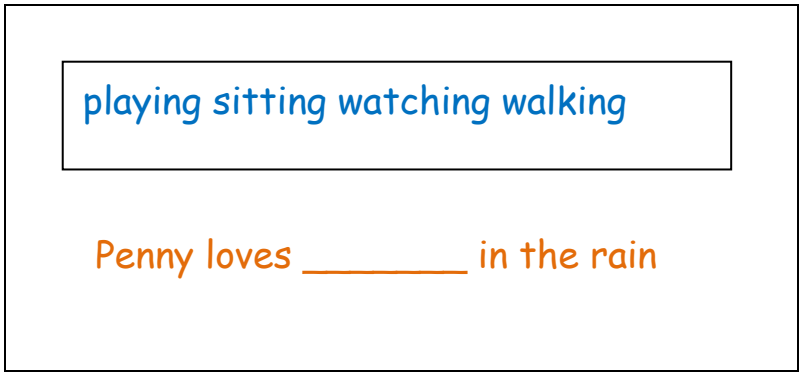

Figure 5: Scenario 2 with “naturalised” sentences similar to the ones children see in class with added ability to drag a word and drop it into the gap

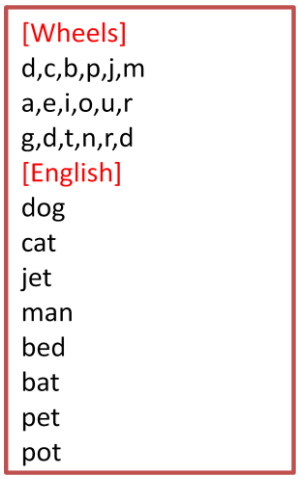

Figure 6: The initial plain text lesson file

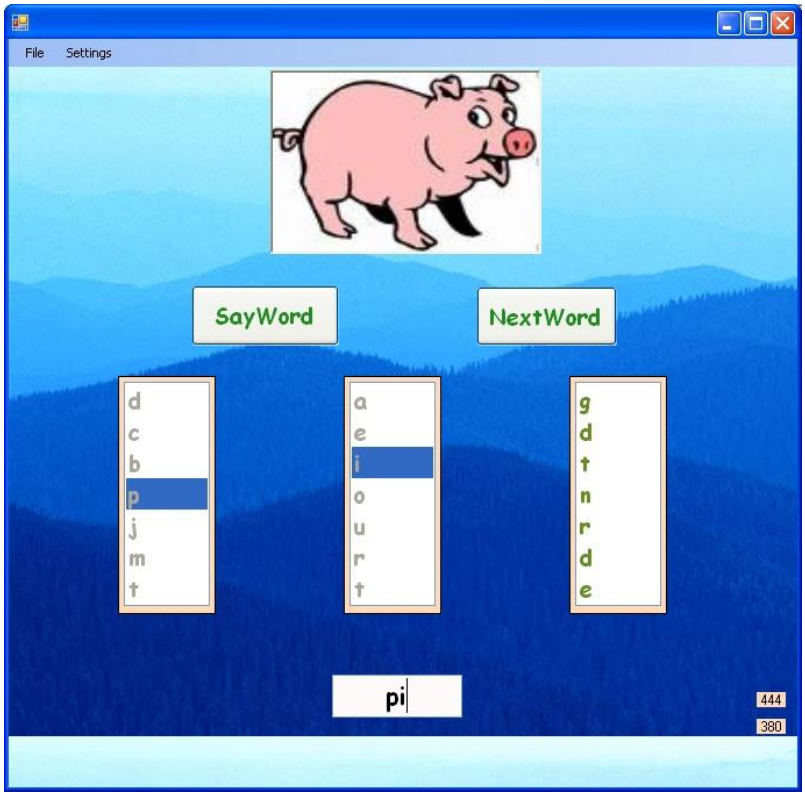

Figure 7: Slot machine user interface

4.1.2 Cycle 2

As shown in Figure 7, the navigation buttons were labelled with text which is not ideal for children who are learning or struggling to read. Since we are dealing with struggling readers it is better to use more visual cues and less text to give instructions to the learners, this way they can concentrate on what they should be reading and not be distracted by trying to figure out what to do to get started or move forward. With this in mind, we cut down on the text and replaced it with pictures; arrows to take one back or forward and speakers for the audio files. We replaced the list boxes with labels on which we could display a variety of "primitive building blocks of language", that is, characters, syllables, words, phrases or sentences. The new user interface (Figure 8) also allowed us to introduce a drag and drop interaction mode where the user could pick a word from a source label and drop it onto a target label. This came in handy in the sentence completion exercise where the learner was required to fill in the missing words in a sentence. Although some researchers [43] say that a drag and drop interface is difficult for children, sitting idly at a computer or just clicking wears out the motivation of the learners with time. Using a drag and drop interface therefore allowed them more control and interaction with the reading software. With a foresight of eventually

catering for touch screens, the ability to pull the correct word into the right place would be quite intuitive.

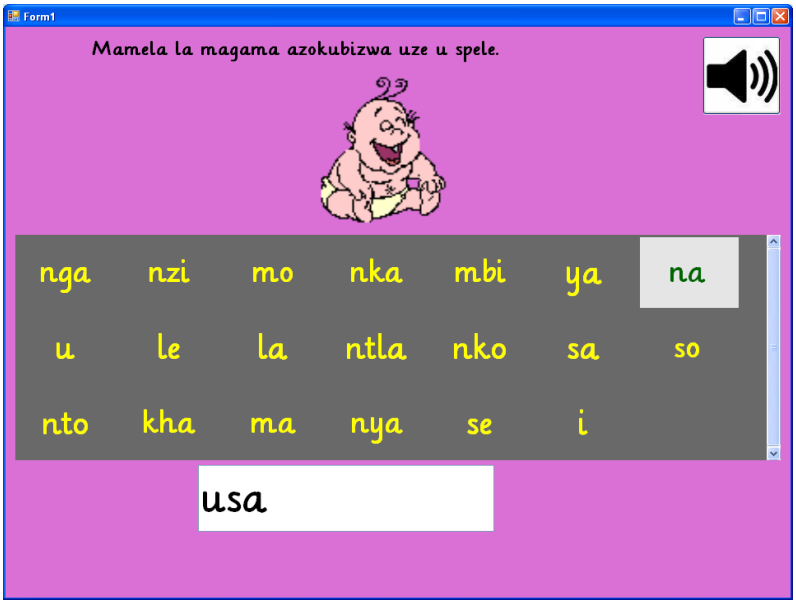

Figure 8: Improved user interface which includes labels on a flow layout panel instead of list boxes

4.1.3 Cycle 3

In the third iteration we introduced a lesson authoring tool (Figure 17) which made it possible for non-programmers to create and edit the lessons to be used in the software. At this point, we also chose to change the lesson files from plain text to XML files (Figure 9). Below are some of the advantages of XML that influenced us in choosing it:

- XML is fully compatible with other applications, and it can be combined with any application which is capable of processing XML irrespective of the platform it is being used on.
- XML is an extremely portable representation to the extent that it can be used on large networks with multiple platforms like the internet, and it can be used on handhelds or palmtops or PDAs.
- XML is an extensible notation, meaning that you can create your own tags, or use the tags which have already been created. This was especially useful in our lesson files where we used our own tags as depicted in Figure 9.
- XML also allowed us to express hierarchical data structures and to easily add attributes to the entities – so that for each element (letter, word, phrase, and sentence)

we could attach references to pictures or sound files. (At this time we do not cater for richer media like video clips, but the extensibility of XML means that it should be possible).

```
<?xml version="1.0" encoding="utf-8"?>

<FMModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" NumWheels="1" LessonKind="Spelling">

  <QuizSentences>

    <Sentence SoundFileName="isele.wav" Text="i[se]le" PictureFileName="isele.gif" />

    <Sentence SoundFileName="unyana.wav" Text="u[nya]na" PictureFileName="unyana.gif" />

    <Sentence SoundFileName="umama.wav" Text="u[ma]ma" PictureFileName="umama.jpg" />

    <Sentence SoundFileName="ikhaya.wav" Text="i[kha]ya" PictureFileName="ikhaya.jpg" />

  </QuizSentences>

  <DictionaryBasePath>C:\BBLit\Media\puzzles</DictionaryBasePath>

  <Language>IsiXhosa</Language>

</FMModel>
```

Figure 9: XML lesson file

4.1.4 Cycle 4

After this we brought the teachers on board who loved the use of multimedia because of its motivational effects and the fact that combining text, visual and audio made word recognition easier. They were however not happy with the font that we had chosen which led us to the fourth iteration where we changed the default font from Comic Sans Serif to Lilly which was closest to the font that the target group was using in the classroom. At this point we created various lessons with the teachers and also recorded the audio files after which we deployed FundaWethu for a usability study, in context, with the children.

4.2 Cycle 5: Feedback from conferences (SATNAC 2010 and RASA 2010)

We presented FundaWethu at the Southern African Telecommunications Networks and Applications Conference (SATNAC 2010) and at the Reading Association of South Africa (RASA 2010) and several questions were asked that helped us to reflect on the software we

had created and make improvements where necessary. This feedback-redesign cycle is a major characteristic of DBR which in turn makes it a flexible methodology.

The first question was about the number of languages that FundaWethu could handle. From the start, our aim was to create software that caters for foundation phase learners who are learning to read in a multilingual context. As a result it was imperative that we create software that could handle various languages. We managed to do this by using a slot machine metaphor that could handle primitive building blocks of language, that is, letters, syllables, words, phrases and sentences. In addition, in section 4.4, we describe how each lesson is created for a specific language. Each different language maps into a different directory structure for its language-specific resources.

The second concern which we had met earlier was that of the font used. The recommended font for South African primary school readers is for sale at a cost of R225 per licence [77]. Considering that the license is a single user licence, purchasing a licence for each copy of FundaWethu would not be cost effective on our part. To solve the font problem once and for all, we decided to make the font pluggable via a setting in each of the reading activities. In this way, the user was given the liberty to choose their ideal font from the font library or add the font to the library. The third question was the issue of availability of the software if people wanted access to it. For this we had to explore different licensing options which are discussed below:

4.2.1 Licensing Issues

Since the issue of availability of FundaWethu came up at the two conferences, we looked into licensing issues to come up with the most appropriate licence that we could use to make the software available. To do this we separated FundaWethu into two components which are going to be licensed separately. The first component is the software itself which includes the delivery engine and the lesson authoring tool and the second component is the content which includes the lesson files and the media files. For the software, we explored the GNU General Public License and Academic Free Licence. We looked into the Creative Commons licenses for the content.

4.2.2 GNU General Public Licence

The GNU General Public License (GNU GPL/GPL) is the most widely used free software license, originally written by Richard Stallman for the GNU project. The GPL is a copyleft

license for general use, which means that derived works can only be distributed under the same license terms [78]. The GPL therefore grants the recipients of a computer program the rights of the free software definition and uses copy left to ensure the freedoms are preserved, even when the work is changed or added to. The free software definition does not refer to price, but rather the liberty one has with the software in terms of copying, changing and adding to the software [79]. Liberty to edit the software means that the source code also has to be made available. As outlined earlier in chapter 3 DBR does not produce a perfect artefact which means that there is always room for improvement. Also due to the contextual nature of DBR, it would be an advantage to make it possible for the software to be tweaked. At the start of our project we set out to create accessible and cost-effective software, citing the high prices of off-the-shelf software as being a hindrance to access in marginalised schools. The GPL therefore would make FundaWethu accessible to everyone even when it is edited or improved by a third party.

Although the GPL offers accessibility, it is still restrictive when it comes to derivatives of the original work. Besides restricting a third party to the same licensing terms, work licensed under the GPL cannot be linked with code that uses a different licence. For example, if one wanted to modify FundaWethu using code from a different project, they could only do so if the second project is GPL licensed. This brings us to another licensing model that has fewer restrictions, the Academic Free Licence.

4.2.3 Academic Free Licence

The Academic Free License (AFL) is a permissive free software license written in 2002 by Lawrence E. Rosen. A permissive free software licence is a free software license that applies to an otherwise copyrighted work [80]. Although AFL grants similar rights to other permissive free software licenses like BSD and MIT, it was written to correct some of the perceived problems with those licenses. For example, The MIT License, which originates at the Massachusetts Institute of Technology (MIT), permits reuse within proprietary software on the condition that the license is distributed with that software [81]. Under AFL 3.0, "*Derivative Works of AFL 3.0-licensed Original Works can be licensed under other licenses, and the Source Code of those Derivative Works need not be disclosed*" [81]. In effect, then, AFL 3.0 is like the BSD license, with no reciprocal obligation to disclose source code. The license is not GPL-compatible, but it can be combined with code that is under a different licence.

GNU General Public Licence	**Academic Free Licence**
- Free software licence - Copy left licence - Reciprocal obligation to disclose code - Cannot be linked with code using a different licence - Open source initiative (OSI) approved - Fedora project approved - Not compatible with Creative Commons Licences	- Free software licence - Copyright licence - No reciprocal obligation to disclose code - Can be linked with code using any licence - Open source initiative (OSI) approved - Fedora project approved - Compatible with Creative Commons Licences

Table 5: Comparison of the GPL and AFL

Looking at the comparison table above, the GPL and AFL are similar in many aspects except the measure of restrictions for derivatives of the original work. Since one of our goals was to make the software "free", AFL stands out as the better option that will make FundaWethu accessible and open to transformation without restriction on the sources used by a third party. The fact that AFL is compatible with Creative Commons Licences also makes it a better choice because we intend to release the content of FundaWethu under the latter licence. OSI approval of AFL is also significant in that we do not intend to restrict FundaWethu to a Microsoft environment. In future it could be deployed in a UNIX environment.

4.2.4 Creative Commons Licenses

The Creative Commons licences are made up of six main licences which vary in their level of restriction [82]. From the start, our intention was to build software that was flexible enough to handle various languages. This we achieved by designing a delivery engine that can handle primitive building blocks of language. From that standpoint, our software can therefore handle a wide variety of content; that is, lessons in different languages and a media gallery to be used with the lessons. This flexibility also means that it is possible to incorporate the context where the software is to be deployed by designing tailor made lessons and recording sound files that the prospective learners can relate to. Taking these factors into consideration, we decided it would be best to release the content under the Attribution Creative Commons licence because the content will be the intellectual property of the lesson author. This license

lets others distribute, remix, tweak, and build upon your work, even commercially, as long as they credit you for the original creation [82]. This is the most accommodating of licenses offered, in terms of what others can do with your works licensed under Attribution.

4.3 Lesson representation

When creating the lessons, the author uses the lesson authoring tool (Figure 15) for describing the lesson and its content. Our presentation engine can read that external description of the lesson and dynamically arrange the layout. Each lesson/puzzle (Figure 10) has four attributes, that is, language, dictionary base path, lesson type and number of wheels. The dictionary base path is the file path to the media repository; the lesson type specifies whether it is spelling, letter-sound recognition etc and the number of wheels specify the number of missing letters, syllables or words. For example, the sentence “Susie loves [dolls]” has one wheel denoted by the square brackets in the lesson file.

Each lesson contains a list of sentence objects which are made up of text, the pre-recorded sound file, and a possibly animated picture file. The text can be any of the building blocks like letters, syllables, and words and we can then attach various animations or sound files to these units, or to the whole sentence. Below is an example of a sentence from a lesson file:
<Sentence SoundFileName="imbi.wav" Text="Iti [imbi] kuba [iyabanda]." PictureFileName="iyabanda.jpg" />

Including the target language as an attribute of a lesson file is important because we created the software to serve in a multilingual context. The same word may need different pronunciations or illustrative pictures in different languages. This allows a "language-contextual" lookup of pronunciations and pictures. We optimized our lesson and media resources by using the word or phrase directly as a lookup key in our media – by default retrieving a picture of "cat" doesn't require the lesson author to do anything other than to drop a (possibly animated) picture of a cat into the appropriate folder. When we want to reuse the "cat" resource in an isiXhosa ("Ikati") lesson, we treat the English folder as a "base dictionary", and provide a simple list of mappings from the isiXhosa dictionary back to the English dictionary. But we also allow specific language dictionaries to override the resources locally. So while "utata" could map back to

"Daddy", it is also possible to override the image in the isiXhosa resources so that we present images that make sense in the culture. Retrieving a picture corresponding to the word "ikati" would first look locally in the isiXhosa dictionary, and only if that was not successful, it would use the mapping to attempt to retrieve the "cat" resource from the English repository.

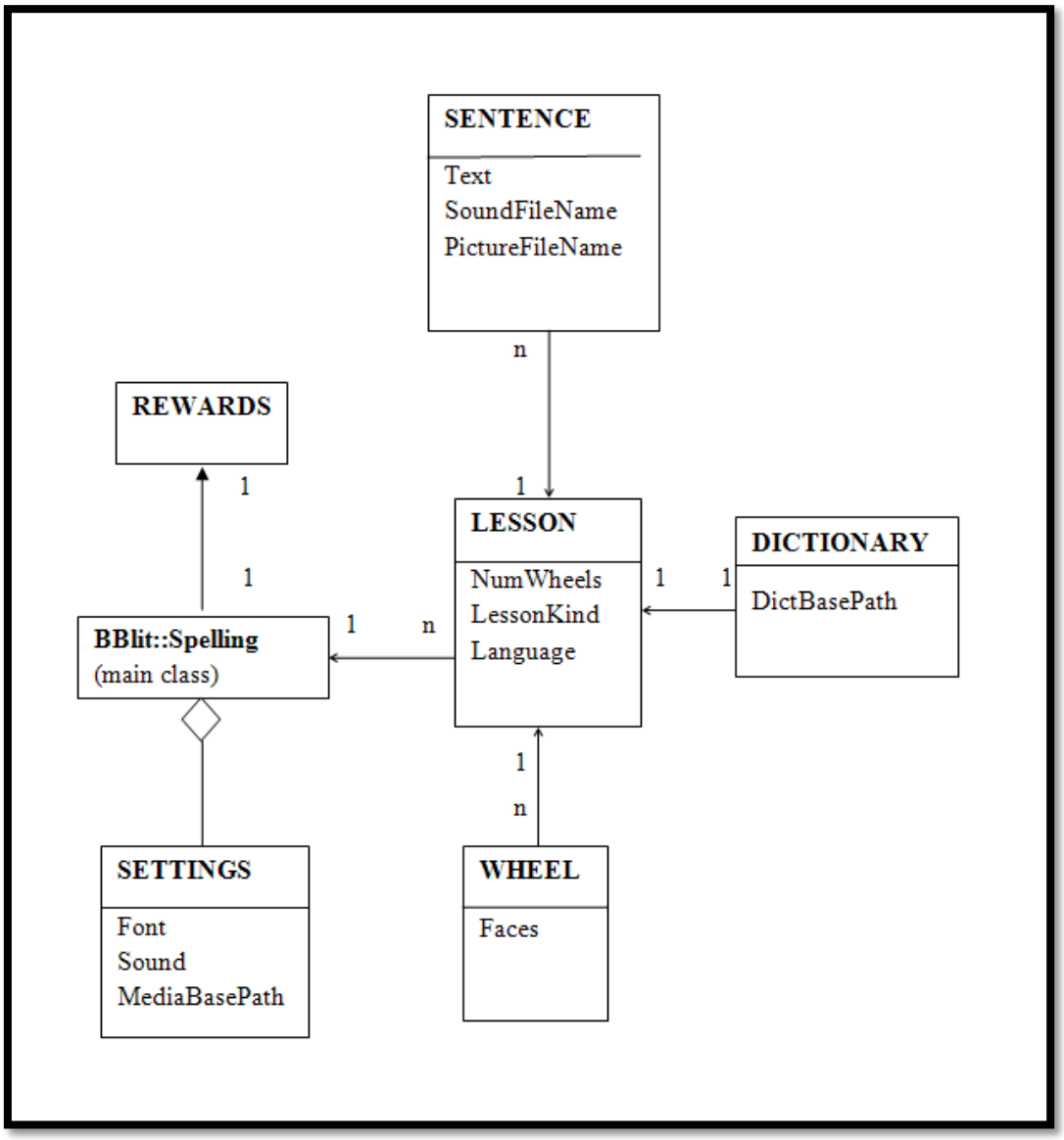

Figure 10: class diagram for the spelling exercise [83]

4.4 Components of the software

Ehri and Wilce [84] performed studies to understand how children became proficient readers and spellers and they centred on word learning rather than reading comprehension. They

observed that word reading skill determines effective reading comprehension in beginning readers. This supports why FundaWethu has much word reading and spelling exercises compared to comprehension. There are multiple ways to read words; one is letter sound decoding rules, another is guessing the word based on context cues or a combination of context and graphic cues and the third is to match the form seen in print with a representation in memory [84]. Although the second one leaves room for error it is effective when learning new words and we have made extensive use of it in FundaWethu. The matching method can develop after being exposed to context and graphic cues and it is fast and reliable and leads to reading fluency. The delivery engine in FundaWethu is the actual presentation of the reading activities and it is made up of six activities. We changed the user interface from the one shown in Figure 5 to make it more interactive (allowing drag and drop) and eye catching (see figures below). Joiner et al. [47] cite a research by King and Alloway which compared children's use of a keyboard, joystick and mouse and found that children of all ages were quicker and more accurate with the mouse. In FundaWethu we thus decided to use only the mouse (clicking and "drag and drop") as a means of input or interaction. This input method is used with the expectation that it will be replaced by touch screen technology in due course. Using a mouse or touch technology also sidesteps the educational concerns about computer keyboards showing only uppercase letters, in a font that does not match their classroom experience.

4.4.1 Letter-Sound recognition

The ability to understand the relationship between a letter and its sound is critical for the development of phonological awareness; letter identification and spelling. The tactile/visual/ auditory features of the computer environment support the active identification of letter/sound relationships [39]. We created this reading exercise (Figure 11) where the learner clicks on a letter or syllable and the corresponding sound is read out.

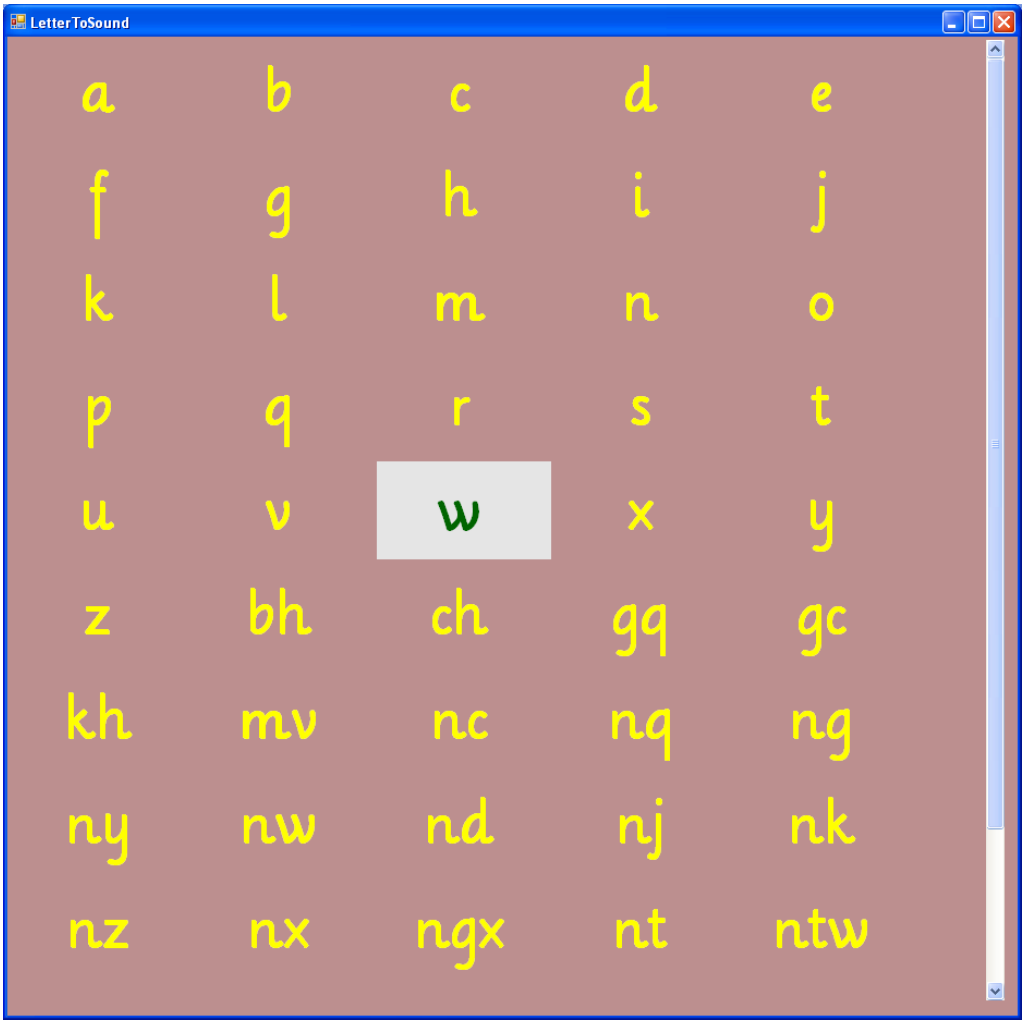

Figure 11: Letter-sound recognition exercise

4.4.2 Sentence Completion

In this exercise the learner has to fill in a missing word in a sentence by choosing from a list of possible words. In a study carried out by Ehri and Wilce [84], one group of first graders practiced reading words in meaningful printed sentences while another group read the words on flash cards and listened to same sentences. Results showed that learners who had read words in sentences were better able to recognize meanings associated with certain spellings while the second group could pronounce the words faster and remembered more letters in their spellings. In our sentence completion exercise we combined both methods were the learners have a separate list of words that they have to read to pick the correct one to complete a sentence. The learners can also listen to the sentence and read it in text on the screen. This helps the learners to understand the meanings of the words in context and also to recognize and pronounce more standalone words.

Figure 12: Sentence-completion exercise

4.4.3 Spelling

Spelling correctly is perhaps one of the most valued yet difficult skills in written communication. Spellings require matching the sounds of language with the appropriate letters in order to accurately and reliably convey messages. A student's ability to spell words correctly shows a sophisticated knowledge of letters, sounds, and syllable patterns [85]. Spelling is an integral part of written communication and an aspect of great concern at schools and tertiary education level and should, therefore, be part of a good computer program [27].

Figure 13: Spelling exercise

4.4.4 Spot Words

A suitable reading program should enlarge vocabulary and improve word recognition [27]. This allows the reader to recognise words quicker and to improve the reader's ability to express oneself verbally and in writing. We included a spot-word exercise specifically for word recognition. We left out visual or graphic cues to help learners 'guess' the words. This meant that for them to be able to recognise or spot a word they had to be able to relate the letters in the word to the sound of the word. In this exercise, four random words are displayed and one of them is read out and the learner has to spot which one was read out. To dissuade the learners from simply clicking away until they reached the correct we put a loud, not-so-pleasant blip for an incorrect word. Because the learners did not like that sound very much, they took their time reading the words and listening to the sound repeatedly so that they could get it right the first time and enjoy the reward music that is played for a correct answer.

Figure 14: Spot word exercise

4.4.5 Flash Card Reading

In this exercise, we simulated a flash card reading system complete with text and visual cues. Just like printed flash cards, a word and corresponding graphics are displayed on the screen for approximately five seconds. Depending on the reading level of the reader as determined by the teacher, the word and graphics are hidden for various amounts of time. Since the learners work in pairs, they have to read the words to each other in turns. After the timeout, the word and graphics are re-displayed and the computer reads the word out. This exercise not only adds to the learners' vocabulary but it also helps them learn the meanings of new words using the graphics.

Figure 15: Flash card reading exercise

4.4.6 Jumbled Story

The jumbled story exercise is the computer version of an activity that the learners in the literacy group do. The child tells a short story which the teacher types on the screen. The story is cut up into individual words and jumbled (possibly with additional distracter words added to the pool for selection). The child then has to recreate their story correctly. This improves their comprehension and creativity and it is a good way to measure their vocabulary. We employed a drag and drop interface for this activity.

Figure 16: Jumbled story exercise

4.4.7 Lesson Author

To help teachers manage the content of FundaWethu we created a lesson authoring tool. This tool allows teachers to create new lesson files, delete, and update and edit existing lesson files. Although the lessons are coded in XML files, teachers manage them via a simple interface (Figure 17 and Figure 18). This means that the teachers do not have to know how to program in xml in order to be able to create lesson files. As shown in the image below, there are two parts of the lesson that are defined; lesson details (Figure 17) and lesson content (Figure 18). The lesson author types the text in the text box and chooses picture and sound files from a gallery. There is preview of the chosen picture to make sure it is the appropriate one and there is an option to hear a selected sound file or create a brand new one to attach to the text.

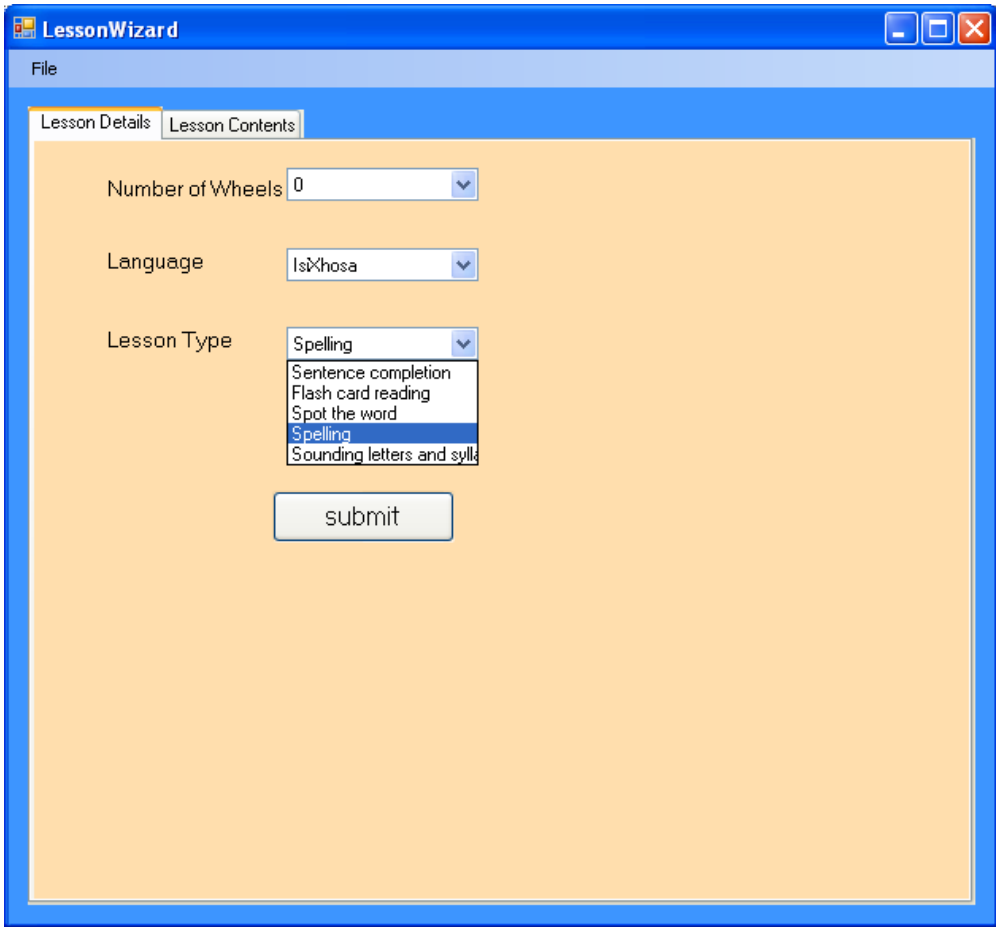

Figure 17: Lesson authoring tool showing the lesson details tab

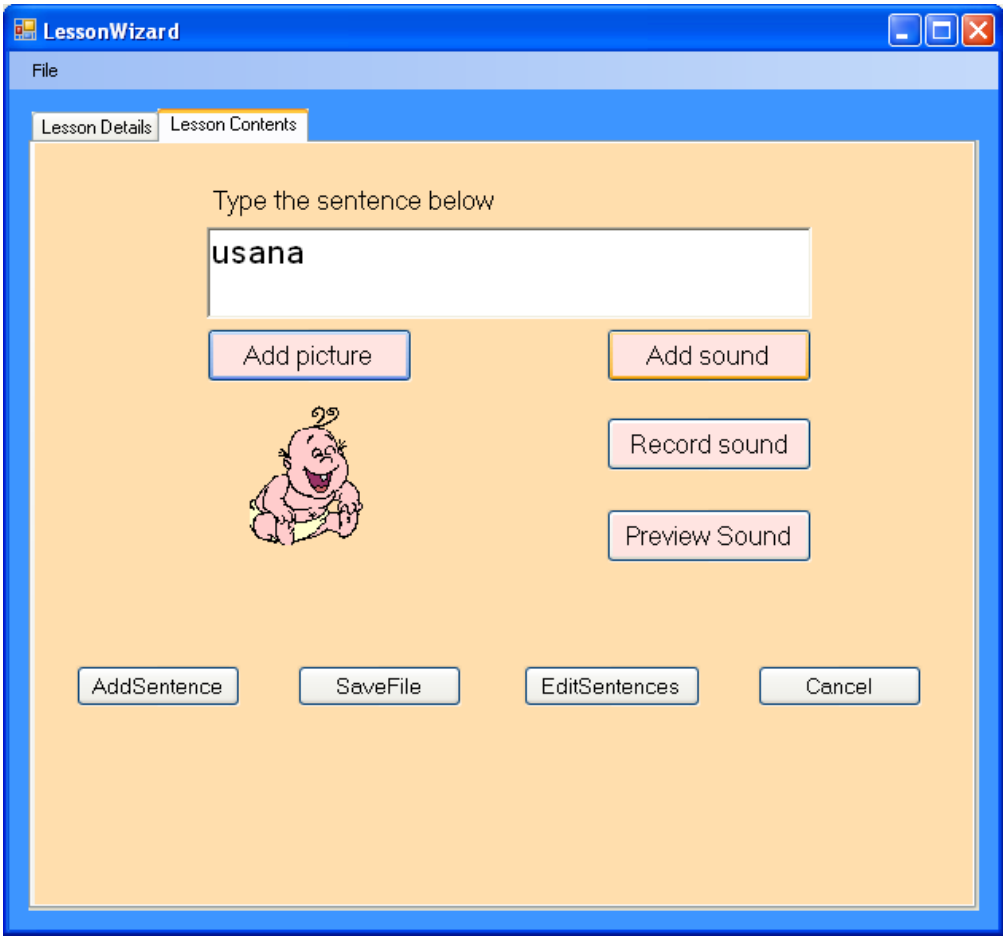

Figure 18: lesson authoring tool showing the lesson contents tab

4.4.7.1 Sentence Editor

When the lesson author wants to edit the sentences in an existing lesson they click on the *EditSentences* button in Figure 18 and a list of all sentences in the lesson is shown (Figure 19). For every sentence, there is an option to delete it, that is, text and associated sound and graphics or to edit the sentence. Choosing any of the two options will open a *SentenceEditor* (Figure 20) form where the text and the names of the audio and graphics files are displayed. The author has the option to totally delete the whole sentence or to edit its text, audio or graphics files.

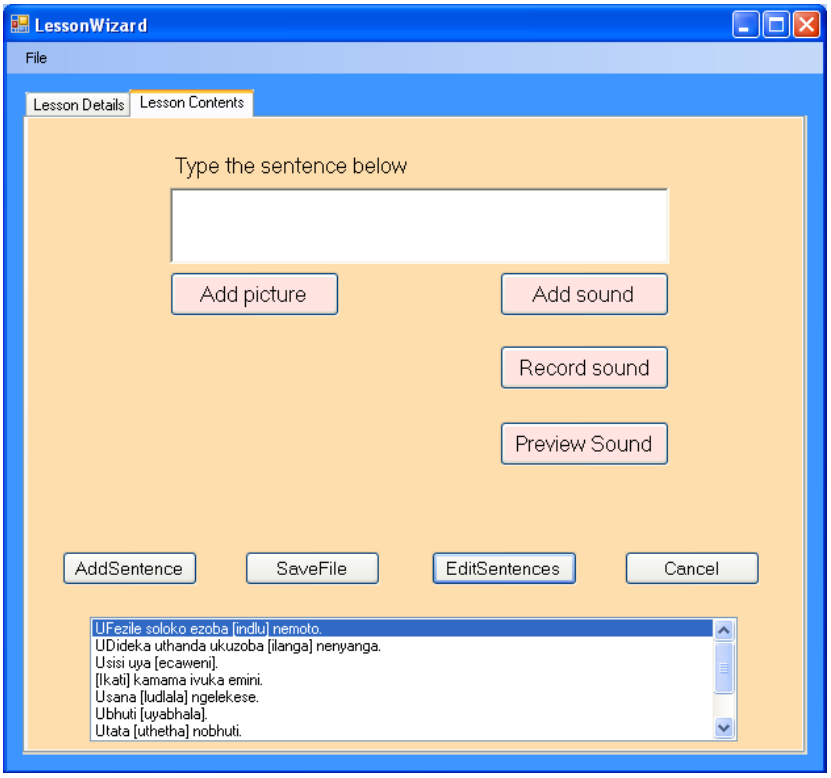

Figure 19: Lesson author showing all sentences in a lesson file

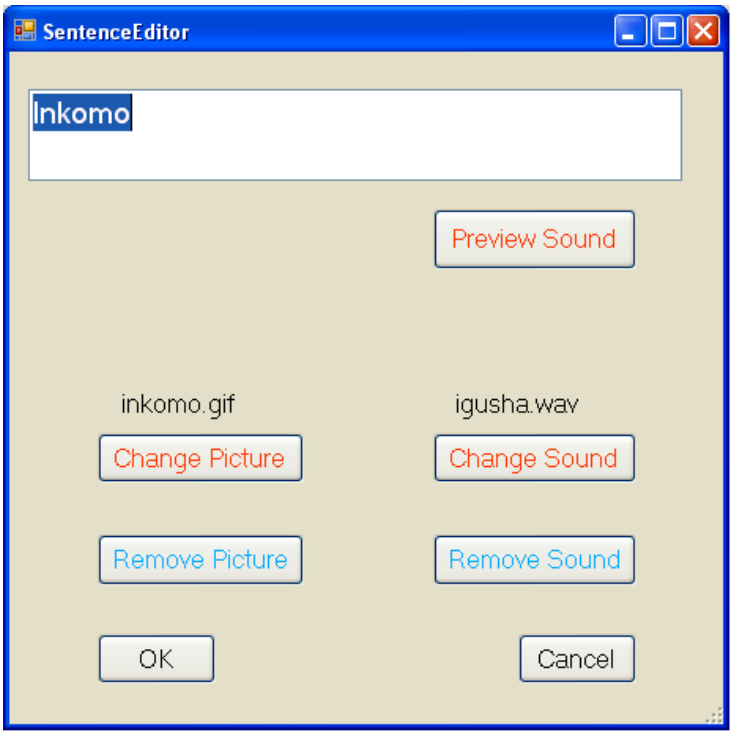

Figure 20: Sentence Editor in the lesson authoring tool

Summary

In this chapter we discussed how we created FundaWethu and why we designed it the way we did. We also had detailed discussion of each activity on FundaWethu. Because of the interest in FundaWethu that was shown at the conferences we participated in, we explored licensing issues to determine the best licence to release FundaWethu under.

CHAPTER 5: EXPERIMENT DESIGN AND IMPLEMENTATION

After designing FundaWethu we went on to do a usability test to determine if we had created a tool that met our user requirements. This chapter explains how we designed and implemented our usability study at our target school.

5.1 What is Usability?

Human Computer Interaction (HCI) is the area where usability emerged. Carvalho [86] reviewed several books and papers that present a definition or characterization of usability. Below is Carvalho's overview of the definitions proposed by different authors [86]:

- Hix & Hartson consider usability to be related to the interface efficacy (capacity to produce a desired effect) and efficiency (competence in performance) and to user reaction to the interface.
- Nielsen views usability as one of the parameters associated with system acceptability. He further asserts that usability has five attributes; easy to learn, efficient to use, easy to remember, few errors, and pleasant to use.
- Shackel proposes that in usability testing, there are four aspects of interest; learnability (easy to learn), throughput, flexibility, and attitude (likeability).
- Rubin accepts that usability includes one of the following four factors: usefulness, effectiveness, learnability, and attitude (likeability).
- For Smith and Mayes usability focuses on three aspects: easy to learn, easy to use and user satisfaction in using the system.

One of our goals was to create software that is adequate for the teacher and learner in our specified context, that is, bilingual learning in the foundation phase. For educational software to be effective, it is important that both the content and the interface be well designed. Since the responsibility for creating educationally sound content lay on the teachers, it was our duty to ensure that the software was usable. In international standards, usability refers to effectiveness and efficiency to achieve specified goals and users satisfaction [87].

> "*Usability: the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.* [87]"

Based on the varying opinions about usability Carvalho [86] concluded that there are two broad areas to collect relevant data to determine usability: system and user performance (includes efficacy, efficiency, easiness to learn and easiness to use); and user satisfaction. We therefore carried out a usability study to collect data about system and user performance and user satisfaction as this would help us determine if we had created adequate software for our context.

5.2 Aims and Methodology

The main aim of the usability test was to determine if we had created adequate software by answering our research question below in terms of system and user performance and user satisfaction:

> *Can we build a cost-effective, fun, language-adaptive and flexible lesson authoring and delivery platform that could assist teachers, researchers and learners involved in bilingual foundation phase teaching?*

Preece [88] suggests that there are four usability evaluation methods that can be used; expert evaluation, observational evaluation, survey evaluation and experimental evaluation. The different methods involve different types of evaluators, different number of users, and different types of data to be collected. With each method there are several techniques such as direct observation, video recording, interactive observation, interviews and questionnaires that can be used (Table 6). In our usability test we used elements of observational evaluation and survey evaluation and our motivation and details follow in the next sections.

Method	**Techniques**
Expert/ heuristic	Walk-through Questionnaires
Observation	Direct observation Video recording Software logging Verbal protocols (think aloud)
Survey	Interviews Questionnaires
Experimental	Software logging Questionnaires Interviews

Table 6: Methods and techniques to collect data

5.2.1 Expert evaluation

Also known as heuristic evaluation, expert evaluation is normally carried out by experts in interface design who help to identify potential problems for less experienced users and possible solutions to those problems [86]. This method is efficient and provides prescriptive feedback. In order to ensure neutrality and objectivity the experts should not have been involved with previous versions of the product under evaluation [86]. Clearly we did not fall in this category because we are not experts in interface design and we are also the designers of the software to be tested.

5.2.2 Observational evaluation

Data is collected that provides information about what users do (behavioural exhibits like smiling or frowning are good pointers to user satisfaction) when interacting with educational software. Several data collection techniques may be used. According to Preece [88] two broad categories of data may be obtained; how users tackled the given tasks, where the major difficulties lie and what can be done; and performance measures like frequency of correct task completion, task timing, and frequency of participant errors. For our usability study we were interested in the first category of data which is how users tackled the tasks given and what could be done to remedy the difficulties they had. This category of data collection embodies what design-based research is about, that is, design-evaluate-redesign. Hanna, Risden and Alexander [70] assert that children aged six to ten are generally not self-conscious about being observed as they play on the computer which makes this method a good choice.

5.2.2.1 Direct observation

Direct observation involves observing users during task execution, with the evaluator taking notes about user performance [86]. This can however interfere with the users' performance, as they may behave in a way they think the evaluator/monitor expects (Hawthorne effect). To avoid such a situation, we decided to use video recording. The recording is then replayed and users' behaviour and problems are analyzed in retrospect. Observing signs of engagement such as smiles and laughs or leaning forward to try things, and signs of disengagement such as frowns, sighs, yawns, or turning away from the computer is a good way of gauging user satisfaction in young children [70]. These behavioural signs are much more reliable than children's responses to questions about whether or not they like something (Hawthorne effect).

Using direct observation, the participant may be invited to think-aloud, when interacting with the software. We encouraged thinking aloud by getting the participants to work in pairs which inevitably led to them talking between themselves as they read. By verbalizing their thoughts, users enable the monitor to understand how they view the software, and this makes it easier to identify the users' major misconceptions or difficulties. From this technique a wide range of information can be obtained.

5.2.3 Survey evaluation

Surveys are employed to know users' opinions or to understand their preferences about an existing or potential product through the use of interviews or questionnaires [86]. It is from surveys that one can get more data about the user satisfaction.

5.2.3.1 Interviews

The interview is one way of collecting data in a survey. There are three main types of interviews [89]:

- Structured where the interview questions are preset and then followed strictly during the interview
- Semi-structured where there are predetermined topics that will be explored but without specifying the exact questions; this can help when different interviewees may require different phrasings and promptings to elicit useful responses. In retrospect this

was particularly useful for the learners we interviewed because we had to rephrase questions and prompt them in order to get "meaningful" responses.

- Unstructured where the interviewer introduces the topic and then allows the interviewee to develop their ideas as freely as possible

We decided to go with semi-structured interviews because they provide a good balance of free-flow and exploration, while also sticking to pre-determined topics of interest [89]. It is easy as a developer or designer to overlook negative aspects of an interface because you know exactly how it functions. Interviews can be a good means of identifying these issues. The Hawthorne effect can also be encountered in interviews whereby the interviewee does not give any criticism or negative comment about the software being evaluated but says what they think the interviewer wants to hear. To mitigate this it is important to emphasize before the interview starts that it is the software that is being evaluated and not the interviewee. It is essential therefore to interview people who are comfortable being interviewed and who are the target users of the tool. Our target users in this case were the teacher (who was helping to monitor the sessions) and the learners.

For the teacher, we divided the interview (Appendix A) into two parts, namely, the delivery engine part (reading activities) and the lesson authoring part. We interviewed the teacher about the delivery part because one of our goals was to create educationally sound software. As the educator, the opinion of the teacher as to the learnability, efficiency, effectiveness and likeability of the software was very important, as was her very valuable contextual knowledge about the children and their skills and needs. The lesson authoring tool is a distinguishing feature of FundaWethu therefore we had to assess its usability too. We interviewed the learners (Appendix B) about the delivery engine to find out their level of user satisfaction.

5.2.4 Experimental evaluation

In an experimental evaluation an evaluator can manipulate a number of factors associated with the interface and study their effect on user performance. It is necessary to plan everything very carefully; required level of user experience, hypotheses to be tested, the structure of tasks, time needed to complete the experiment, and so forth.

Normally, a combination of methods is selected according to the needs and constraints of a project. The selection of a method has to take into account the techniques for data collection that can be applied. For this project we selected observational and survey evaluation. Since we were working with one teacher and 10 learners, we decided to do interviews instead of questionnaires to get their opinion. We also did direct observation of the learners at work and did video recordings of the usability study sessions.

5.3 The computer lab: Test environment

We revived the school computer labs by repairing four of the faulty computers. The lab had a total of five working computers all running Windows XP with the .NET Framework 3.5. We connected external proline speakers to each computer (Figure 21) and got learners to work in pairs on each computer (Figure 22).

Figure 21: Work station in the computer lab

Figure 22: Participants working in pairs

5.4 Demographics

All participants chosen were part of an already running reading intervention that was done at the school weekly [90]. All learners in the after school reading program underwent a reading and writing pre-test (as part of the existing intervention, not specifically for our purposes). Using the results the students were divided into three groups; good, average and struggling. For our usability study we chose ten students who were classified as average readers in the pre-test. Of the 10 students, 6 are in grade 2 while 4 are in grade 3. The group of students had an average mark of 25.5 out 40 in the reading test. The school from which we took the participants is in a marginalised area of Grahamstown were most students are economically disadvantaged. Of the 10 participants only two were female. A greater number of participants had not used a computer before with only 40% having occasionally played computer games at home and at the BingBee kiosk [91]. This general lack of computer literacy worked in our favour because the participants represented our target users, that is, marginalised schools with little or no access to computers. These are the schools where reading is taught mainly in indigenous South African languages. From this background we could measure how learnable FundaWethu was even with little or no computer experience.

5.5 Limitations

One major limitation we encountered was that we joined an already existing reading program therefore inheriting all its problems. From the start we envisaged we would have ten solid sessions starting on the 19th of April. Because we were working in natural settings with unexpected changes, we could not get consistent meetings because in April and May we only had three meetings and three cancellations due to teachers' meetings. Straight after this, it was vacation time for the learners and instead of the six sessions we had hoped to have in that term, we only managed three. After the June holidays, we only managed to get three and lost out four sessions due to the public service strike in late August to early September. After the strike, we managed to get four more sessions to make up the ten initially planned. Although we reached our target sessions, there was a lot of inconsistency in our meetings which does not work in the learners' favour because CAI success requires consistent high usage patterns [15]. The untimely cancellation and postponing of the weekly meetings also set us back in data collection and refinement of FundaWethu. One noteworthy observation which perhaps points to the learnability of FundaWethu is that, after four weeks of not using FundaWethu (public service strike), the learners still knew their way around FundaWethu. Although the level of computer literacy/computer exposure of our participants was representative of our potential target users (struggling readers learning to read in bilingual settings in marginalised schools), it limited the quality of responses that we got from participants in the interviews. This is probably because our participants were in the informational stage of IT knowledge acquisition as outlined by Wong [16]. In this stage the user has gained novice level of ICT skills and knowledge but has insufficient confidence. Using direct observation in our data collection minimized this negative result.

Summary

In this chapter we discussed the methods and techniques that we used to carry out our usability test; the advantages of such methods and the measures we took to counter potential shortcomings. We also described how we carried out the usability test, the demographics and the limitations we had in carrying out the usability test.

CHAPTER 6: FINDINGS AND DISCUSSION

To discuss the findings from our usability study, we began with a comparison of FundaWethu to similar interventions, Project LISTEN and the MacMillan Talking Stories. We then discussed in detail the results of our observational evaluation together with results of the teacher and learners' interviews.

6.1 FundaWethu VS Project Listen and MacMillan Talking Stories

G. Ayorkor Mills-Tettey et al. [28] outline experiments that were done with Project LISTEN's Reading Tutor in Ghana and Zambia. The reading tutor used automated speech recognition to provide a guided reading experience for the user. Just like FundaWethu the Reading Tutor was deployed in a bilingual setting (children speak a native language at home and learn in English at school). The project was done in developing communities with under-resourced and overcrowded classrooms which offer little individual attention.

They reported that the first hurdle the participants encountered was with regards to understanding the instructions given by the Reading Tutor. This was because of the American accent and vocabulary that was used which was not exactly what the children were accustomed to. From the onset, because of the multilingual goals, we decided not to attempt to recognize or synthesize speech. Instead, we have provided the ability to use pre-recorded sound clips of spoken words, phrases and sentences. This offers us a very flexible mechanism with excellent quality, and makes it easy for the lesson designer to add new words, sentences, or sounds.

In Project LISTEN, even though the learners had little computer experience, most of them could work on their own after two sessions with the Reading Tutor. Using the Reading Tutor it was observed that children who did not have much prior experience with computers were easily engaged with the tutor. This is important when using technology for learning because the level of engagement influences the software's effectiveness. It was also observed that some of the participants did not understand English well enough to benefit from using the Reading Tutor. To avoid this situation, local language content could have been highly

beneficial. This is one factor that we kept in mind and incorporated into FundaWethu during development.

In Project LISTEN, children who were fluent readers with computer experience seemed to get bored and easily distracted and they did not exhibit any change in their reading abilities. Targeting struggling readers for computer assisted instruction therefore has a better prospect for success. Although the Reading Tutor was designed for use by a single user at a time, the researchers noticed that children would gather around a single computer and try to help each other. This is a trend that has been observed in other technology interventions in developing communities [92]. For this reason we decided to pair up (co-discovery exploration) the learners when using FundaWethu.

Locally, Macmillan Talking Stories (MTS) which was developed by Kathy McCabe [34] presents stories in English, isiXhosa and Afrikaans. The talking stories allow one to hear a story read to them while they follow it on the computer screen. Instead of someone pointing their finger to each word, the learner will see each word highlighted as it is read. MTS also has a translation mode where one can hear a story in their home language to build understanding before reading it in English. Every story comes with three interactive reading activities. These activities are fun and bright, and greatly loved by children. Unlike the Reading Tutor, MTS takes into account the bilingual context that children learn in and incorporates home languages. This is the same thing that we did in FundaWethu because research shows that reading in the mother tongue improves chances of learning a second language. MTS was built to be as teacher proof as possible because of the shortage of teachers in South Africa. All instructions and prompts are therefore sound-based and the child just has to know how to click and drag before they start using the software. This is a component that we also introduced in FundaWethu so that reading instructions do not become a hurdle to using the software beneficially.

Unlike MTS, FundaWethu explores reading from the primitive building blocks of language, that is, letters, words, phrases, sentences and stories. This we did by incorporating the foundation of learning to read which is, letter-sound recognition. So learners in FundaWethu are taught not only to read words but to actually build them, starting with simple words until they can build an actual story. FundaWethu will also offer the flexibility of allowing

educators to design and update the tutor content to suit the learners they are working with. This aspect of flexibility is seldom available in reading tutors therefore it hampers localization of content. Localising content helps to build meaning by introducing learners to what they know and see every day before introducing the unknown.

6.2 Results of the experiment

In the enactment stage of DBR, there are successive iterations and we noted these iterations at 2 levels; software design and the lesson content. We had about 10 sessions of the usability study and at every session we got feedback that we incorporated into FundaWethu to improve it. We devoted the first session to computer training because we were working with children who had very little computer experience. As expected there was initially some fear from the learners and they struggled with moving the mouse, pointing and clicking. As their curiosity got the better of them they became more relaxed and started exploring the computer a lot more. By the end of the session they were very excited about this new venture and looking forward to the coming sessions. We did a walkthrough of the letter-sound exercise and the first negative feedback was about the font we had chosen. When learning to read, the font used is very important and since FundaWethu was a supplementary tool, it was important to make sure the font used was similar to that used in the classroom. The font became the first thing we changed in the software from the first session of the usability study.

We designed FundaWethu in such a way that the tasks in an activity are displayed randomly. In this way we avoided a situation where all learners were spelling or reading the same word at a time. This reduced the chances of learners copying from others without actually doing the task at hand. On the hand, we noticed that children were getting easily distracted by the sound coming from the neighbouring computer. The classroom environment is usually “noisy” so we decided we would observe this aspect for a while before converting to use headphones. In the second session we noted that as the learners got more comfortable, the noise “faded into the background” and each pair was engrossed with what was happening at their computer. At the end of the session we asked the children some random questions about the computer. All of them said they loved the person who was talking in the computer because the person could tell them how to read a word many times. Repetition is one of the things that put CAI at an advantage in comparison to traditional classroom learning. The audio rewards also kept the learners motivated and they could be seen dancing whenever they got an answer right.

In the second session the computer fascination was less and the learners focused more on the reading. In this session we introduced the second activity, spot-the-word exercise which used text and audio aids. It was in this session were we noted some errors in the content, for example, missing pictures and sound files that were not audible. As discussed earlier recording our own sound files offered us flexibility and localisation of content but it raised the challenge of having good equipment to record with. Poor recording equipment or a noisy environment meant that we got low quality sound files. One of the aims of this software was to make it cost-effective so it is likely that one would think the cost of recording equipment nullifies the initial goal. From our recordings, we found that using simple headphones with an attached microphone produced better sound quality than using high quality microphones with a mixer. This is because the high quality microphones could pick up the slightest background noise. Potential users of FundaWethu can therefore spend approximately R200 to buy headphones and record their own sound files. In this session we also noted a logical error in the progression of the game. We ordered lessons in levels of difficulty and at the end of each lesson the user had to close the application and reopen it to select the nest lesson. This was not only tedious but it disturbs the flow of reading. Since DBR permits us, we went back to the drawing board to correct this to include continuity from one lesson to the next and the option to repeat the level (Figure 23). We also recorded new sound files to replace the ones that were not audible.

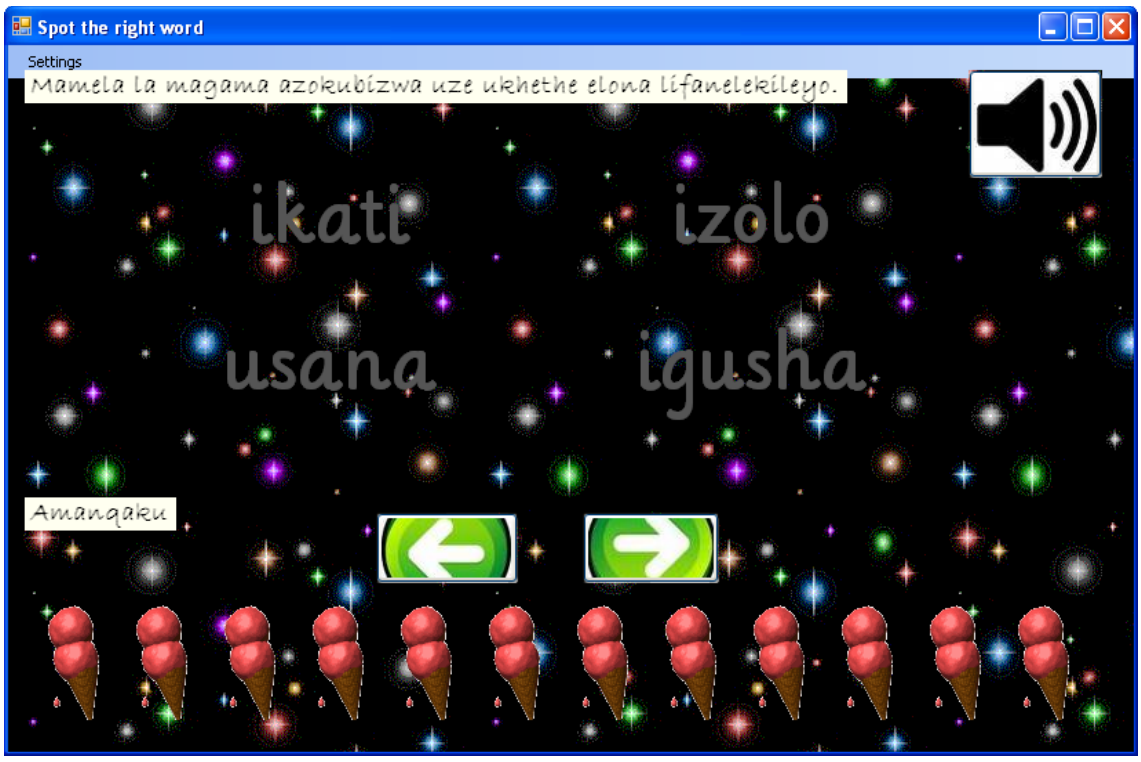

Figure 23: Spot-the-word with faded words with options to go back or forward as shown by the arrows

In the third session we introduced the flash-card reading exercise. As the learners were doing the exercise, we observed a serious logical error because they could "cheat" their way through the activity without actually reading. The activity required very little interaction which wasn't appealing to the learners so they kept clicking until they found that they could get away without reading by continuously clicking the next arrow. This obviously defeated the flash card reading objective so we had to make sure we deactivate the navigation arrows as soon as a word was displayed until it was redisplayed in preparation to go to the next word. This measure worked because the learners worked in pairs and they acted as supervisor for the other because the activity had no inbuilt way of determining if the learner had read the word correctly. There does not seem to be a simple solution to this other than providing technically complex speech recognition to validate if a spoken word is the correct word.

All the remaining sessions were pretty much smooth sailing except for one installation flaw that came to light when we introduced the spelling activity. We designed FundaWethu on a computer with a twenty three inch LCD monitor and therefore sized all the windows forms accordingly. This was obviously a big oversight because we installed FundaWethu on computers with smaller CRT monitors, seventeen inches. As a result, all the controls on the forms where thrown off as the forms were forced to resize to the new screen size. We decided the solution would be to set the forms to a standard maximum size of 960x760 in order to fit the size of the monitors in the computer lab. As it turns out, these are the types of monitors that are commonly found in schools and the forms still look clear when taken back onto a larger screen.

In our observations we found that the learners quickly adapted to using computers for reading. Although they had a bit of trouble dragging and dropping when we introduced the sentence-completion exercise, they got the hang of it by the end of the session and they loved by the measure of control they had compared to clicking. By the fifth, the learners could switch the computers off and on to start reading just by watching us the co-coordinators doing it.

DBR is a highly contextual methodology and incorporating a lesson author into FundaWethu allowed us to contextualize the reading content. The fact that the lessons were done by the

teachers meant that they could link them to their syllabus therefore reinforcing what was being learnt in class. On top of that, the learners could learn a lot more new words per day using FundaWethu. A comment form one of the learners after the first session was that they had seen new syllables that they had not seen in class. In this regard, FundaWethu did not only supplement and reinforcing reading, it placed them a step ahead. This was confirmed by the teacher that when she introduced new syllables in class, the learners doing the usability study were quick to recognize the new words and teach others. By recording their own sound files, the teachers created sentences and stories that learners could relate to therefore incorporating their social context.

6.3 Teacher interview results

We carried out an interview (Appendix A) with the teacher concerning FundaWethu since she plays a pivotal role in the sustainability or continuity of the project. We asked questions about the frequency of use, the learnability of the software, the user interface, benefits and difficulties perceived. The general observation from the teacher was that children had difficulties learning to use the computer and not the software itself. She was of the opinion that the instructions given to the learners were clear and easy to understand. The learners did not struggle when navigating the user interface because it was minimal and with clear prompts. The teacher also noted how learners benefited in terms of confidence which was exhibited even in the classroom. Being in the computer group made them "feel special". She however highlighted the issue of sound because two learners had a hard time hearing the sound. Although it later emerged that some clinical tests done on them at the start of the after-school reading programme, showed that they had hearing problems, the problems were obviously still persisting even if the learners were treated. After the initial treatment, nothing else was done about the two learners' hearing problems. The question therefore arises of whether headphones instead of speakers would be a good option for such learners. One of the conditions of success for CAI is high use patterns, the teacher also highlighted that if the learners were to benefit fully from software like FundaWethu they needed more practice.

We got together a group of six foundation phase teachers (including the teacher who was part of the usability study with the children) to train them on using the lesson authoring tool to create and edit lessons. The training session lasted one hour. Out of the six teachers, three were computer literate so it was easier for them to use the lesson authoring tool using the

instruction manual (Appendix C). They particularly liked the fact that they could record their own sound files. We then went on to interview (Appendix A part B) four of the teachers (the other two were not available) concerning the lesson authoring tool asking questions about the interface, the activities they did using the authoring tool, the good and the bad points, and the level of difficulty of using the tool.

The general consensus from the teachers who were not computer literate was that, using the authoring tool was not difficult; their challenge was that using computers was new to them. All the teachers thought the authoring tool interface was simple and easy to navigate; coupled with the user manual, it was easy to use. One teacher particularly liked the fact that she could preview chosen sounds while creating lessons. This made it easier for her to sample the different sound files and select the most appropriate one. The teacher emphasised the importance of knowing letter-sound relationships so the recording capability of the authoring tool would help the learners in this regard. When asked about the usefulness of being able to create lessons, one teacher said that it allowed them to incorporate the immediate needs of the children as observed in class.

One interesting issue raised by one of the teachers was that the learners could use the lesson authoring tool to cultivate their creativity. In other words, they could write their own sentences and attach pictures and sound files to the sentences. Although we have the jumbled story activity to foster creativity, the teacher's idea could be a good one to consider for future work. This particular teacher liked that when selecting a picture one could see a snapshot of the picture, which, coupled with audio would be a good thing for learners to do.

Regarding the level of difficulty of the software, all the interviewees thought other teachers in similar situations would find the authoring tool easy to use especially if they devoted themselves to practising. One teacher noted that indeed computer illiteracy on the teachers' part affected the access that learners had to computers (if the teacher is not comfortable with their computing skills they do not take the learners to the lab because they do not want to teach the wrong thing). Another teacher noted however that the availability of FundaWethu in the computer laboratory would make it possible for them to practise and be ready to introduce Grade one learners to FundaWethu next year.

6.4 Results of the interviews with the learners

We carried out interviews (Appendix B) with five of the ten learners to gauge their user satisfaction. Children aged between six and seven may be a little shy or inarticulate when talking about the computer. Since interviewing young children yields unreliable results in comparison to direct observation, we treated the interviews as reinforcements and also a platform for learners to voice what they may not have voiced during observation. Our learners were aged between six and eight and they were not articulate when answering questions but they still raised valuable issues which will be discussed below.

We interviewed the learners one at a time with their teacher present to ask them questions in isiXhosa and help them to be at ease. The reason why we did this was because in the usability study sessions when we asked them questions they all gave the same answer as the one given by the first one to answer. Separating them was therefore a measure to get their individual thoughts. We asked learners some questions about what they did and did not enjoy using FundaWethu, what was most difficult, their preferred interaction mode and if they wanted to continue using the software. All the learners stated that they enjoyed using the computer to read for various reasons which include the following:

- they learnt new words in every session and in turn they could help others in class when they encountered the same words
- they learnt how to use the computer
- one learner said he loved hearing his teacher read to him on the computer. As discussed in chapter 4, the teacher recorded all the sound files that we used with the lessons and the learners recognised her voice. This made us ask the question whether this personalisation of the lessons could help the children learn better. Personalised learning is about tailoring the curriculum and teaching methods to the needs of pupils so that all can progress, achieve and participate [71]. It strengthens the link between teaching and learning by engaging pupils, and their parents/carers, in learning. Personalised learning focuses on pupils with learning difficulties which include reading. The lesson authoring tool makes it possible to tailor lessons to the need and aptitude of an individual and goes further to allow recording of sound files and using a voice that the learner is familiar with.

All the learners thought dragging and dropping was the most difficult thing to do using FundaWethu. Ironically when asked which method they preferred between clicking and drag-and-drop, all but one preferred drag and drop. This suggests that children like a measure of challenge and control where they are part of the "action" [52]. When doing the drag-and-drop interaction, we simulated actually lifting a word and dropping it onto the right place. So whenever the learner clicked on a word and began to drag it, we replaced the default cursor with an image of the word so that the word could be seen virtually moving from one place to the next. In comparison to pointing and clicking, drag-and-drop was more engaging. Some of the learners also thought the sentence completion exercise was difficult because they had a hard time deducing which word was missing from a sentence. This is despite the fact that they could replay the full sentence countless times which is indicative of their low comprehension levels. This exercise combined word recognition (picking the right word from a pool of choices) and comprehension (listening to the full sentence, reading the incomplete one and determining which word was missing). The ability to make such observation makes FundaWethu a useful platform for assessing children's performance or reading competency.

Overall the learners were happy with FundaWethu and would love to continue using it. Below is an excerpt of a word of appreciation from one little girl:
"*Ndifuna ukuthi kusisi undincedile kakhulu ngokundifundisa i-computer, bendingazazi izinto ezinzima, bendisazi ezilula, undincede kakhulu*"
Translation: I want to say to *sisi* (isiXhosa show of respect for a woman who is older than you) she helped me a lot by teaching me how to use the computer. I did not know difficult things but I only knew easy ones so she helped me a lot.

It is remarks like this that show how much FundaWethu helped boost the learners' confidence and motivation as corroborated by their teacher. This sort of confidence makes the learners look forward to learning new things every day as was shown by the excitement the learners had prior to all our sessions. On one occasion I went up to the school to interview the teacher and the minute I walked into the classroom, all participants in the FundaWethu usability were beaming. This alone was indicative of the extent to which they liked FundaWethu [70].

Summary

From the discussion above, we can conclude that the observational evaluation during our usability test yielded data that we used to refine FundaWethu to meet the needs of the users. The interview with the teacher consolidated these observations. Contrary to our expectations, the interviews with the learners were particularly enlightening. They responses raised the issue of personalized learning that we had not really picked throughout the project. Their satisfaction in using FundaWethu also gave us confidence to assert that we had developed an adequate tool.

CHAPTER 7: CONCLUSION AND FUTURE WORK

As noted in chapter 1, this project had three major themes: the Design-based research methodology and its use for building systems like FundaWethu, the design and construction of the artefact, and the usability study / intervention that we did. All three themes were inter-related as follows; design-based research which includes informative exploration led to the initial design of FundaWethu and the usability study fed into the cyclic refinement of FundaWethu as part of design-based research.

As expected, carrying out this project presented some challenges which we had to work through. The major challenge which has been noted in other DBR projects [58, 91] [65]; was striking a balance in the teacher-researcher relationship, which is, getting to a position where each party pulled their weight in ensuring the success of the intervention. Compared to experimental research, DBR offers flexibility which was important to the success of this project because it allowed us to change the 'conditions of success" as we went along. To do this, we took two measures that were suggested in the DBR review by Anthony Cocciolo [65]. The first measure was to make the artefact "teacher proof" which meant that learners could use it on their own without any administrative help from the teachers. The second measure was to train the teachers in using the software because that skill increases buy-in and motivation from the teachers which is important in the success of the intervention [15]. Despite these challenges and many cancellations (teacher meetings and the public service strike) of the usability study sessions, we were able to get valuable information that helped us to refine FundaWethu into an adequate tool for our users. An observation by their teacher with regard to better word recognition and retention because of the exposure they had to hundreds of words using FundaWethu shows that the usability study also helped the learners in their reading.

When we embarked on this project we set out to answer this question: *Can we build a cost-effective, fun, language-adaptive and flexible lesson authoring and delivery platform that could assist teachers, researchers and learners involved in bilingual foundation phase teaching?*

The ability of our lesson author and delivery engine to handle primitive building blocks of language made FundaWethu both language-adaptive and flexible. The lesson author itself also brought some flexibility into the software because it allowed teachers to add and edit lesson files that the learners used. From the observational evaluation that we carried out, the learners showed and verbalised how much they enjoyed using the computer to read especially the multimedia aspect. This is an indicator that we managed to capture the fun aspect as we intended initially. The fact that the reading content can be edited and added to makes the software cost effective because it is re-usable.

As stated by Dede [64], DBR should be evaluated at two levels; the design of the artefact and the implementation (conditions of success). The design considerations and design process ensured that we built an adequate and workable system that was sufficient for our needs, and allowed for enough flexibility to cater for a number of different lesson types. In terms of design, our metaphor of a gambling fruit machine has been a successful and powerful tool, allowing us to use a common representation to build quite a wide range of different exercises that can exercise skills around letters, syllables, words, phrases or sentences and at the same time address the five essential reading areas, which are, phonemic skills, phonics skills, vocabulary, fluency, and comprehension. By providing recordable fragments that we can attach to any element of the lesson, we've achieved flexibility whereby new sound files can be added as need arises. In comparison to using text to speech synthesizers, recording our own sound files gave us better sound quality especially where pronunciation of words was concerned. Using the lesson authoring tool, we made it easy for the teachers to add sounds and images of their own with an option to record new sounds while they are creating lessons. We also created an extensive language-specific media gallery from which teachers can choose pictures that they intend to use.

Considering we were working with people who were initially computer illiterate, we used a simple file system rather than a database to store our media content. This was to make it easier to deploy and easy for the teachers to use it without having to burden them with learning how to use databases. By making the software language-aware, and by using an object-like inheritance system simple lookup translation for nouns, we've been able to customize and override any audio or image resources to make them culture or language specific, but at the same time we can efficiently share those resources that do not require customization

Although we had a great working relationship with the teachers in terms of designing the software and creating the content, we encountered challenges in the actual intervention. This was caused by the fact that we joined an existing school program and inherited all their challenges, the major one being sudden meeting cancellations. According to our interview with the teacher, FundaWethu is a tool that could significantly improve literacy levels because it motivates and boosts the learners' confidence when reading. Improvements were already noted in the classroom when the learners could quickly recognise and read new words that they had encountered while using FundaWethu. The importance of high use patterns cannot be ignored if an intervention is to succeed.

Although FundaWethu is multilingual in terms of lessons it has little capability for internationalisation. This is because the labels and window titles are mostly in English with a few labels written in isiXhosa. It might be a worthwhile extension to extract those resources into a language-localisable file just like we did with the lessons.

To determine if we had developed software that is fun, we analysed the behaviour of the learners as they used FundaWethu [70]. We observed that the learners were always eager to come for the weekly sessions with the occasional one or two absent. When the learners sat at their computers, most of them were engrossed in their reading as shown by the way they leaned forward to read. The sound files we played were an added bonus because at every success, they would be seen celebrating or doing a little dance. This kept them motivated to read some more and get more rewards. In their interviews, they made it clear that although they encountered difficulties, they loved FundaWethu and wanted it to be introduced to the rest of the school to benefit everyone.

Although the students were paired up in the usability study, none of the activities inherently promote co-discovery. Possible future work could be to include activities that promote co-discovery so that as the learners read, one does not become a spectator but instead both learners have shared control.

All the unexpected challenges we encountered are characteristic of design-based research which is done in natural settings with dynamic variables. Despite these challenges, we were able at the end of the day to build a tool that meets the users' requirements and has the

potential to improve the learners' literacy if used regularly. One useful recommendation to anyone who would consider doing a design-based research project is to do a thorough informative exploration before the start of the project so as to anticipate some of the potential problems and put counter measures in place.

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APPENDICES

Appendix A: Teacher interview

PART A: Lesson delivery

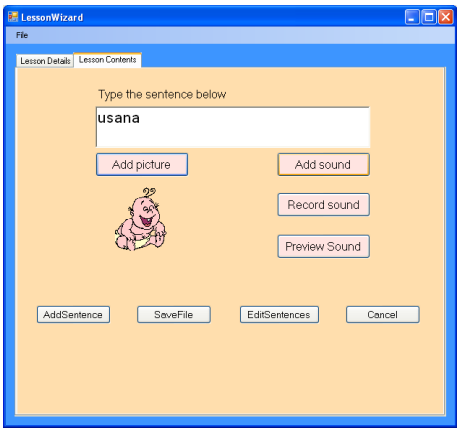
1. How many times did you use the software?
2. What kind of activities did you do when using the software? Rank the following in order of importance (1: most used – 5: least used)
    - reading
    - listening
    - writing
    - pronunciation
    - other
3. What was your purpose in using the software?
4. Regarding the level of the software, do you think it was this too difficult, about right or too easy for the children?

Activity	Too difficult	About right	Too easy	Suggestions for improvement
				
				
				

5. Did you understand the instructions?
    - yes
    - somewhat, but not completely
    - no
6. Was the interface easy to navigate?
7. What benefits did you perceive from using the software?
8. How useful did you think your use of the software was for the learners, and what do you think it enhanced? Where could you see the benefits coming out for the learners?
9. What was the most difficult thing to do or to get used to when using the software?
10. List the good points and bad points of the software.
11. Would you like to continue using this software?

PART B: Lesson authoring



12. What kind of activities did you do when using lesson author?
    - recording sound files
    - writing lesson files
    - editing lesson files
    - other
13. Do you think it is useful that you can create lessons for the children, why?
14. Was the interface easy to navigate?
15. What was the most difficult thing to do or to get used to when using the lesson author?
16. List the good points and bad points of the lesson author.
17. Would you like to continue using this lesson author?
18. Regarding the level of the software, do you think other teachers in a similar situation to yourself would find this software
    - Too difficult
    - About right
    - Too easy

Appendix B: Learners' interviews

1. What did you enjoy about using the computer to read?
2. What did you not enjoy about using the computer to read?
3. What were you able to do that you could not have done in class?
4. What did you find the most difficult thing to do using the computer to read?
5. Between clicking and drag-drop, which one did you like more?

6. Would you like to continue using this software?

Appendix C: Lesson authoring tool manual

The lesson authoring tool allows you to create lessons for the following activities:

Spelling

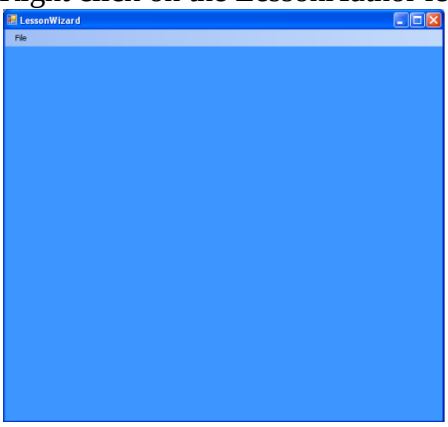
WordReading

SentenceCompletion

SpotWord

Steps to create a lesson

1. Right click on the LessonAuthor icon and click **Open**

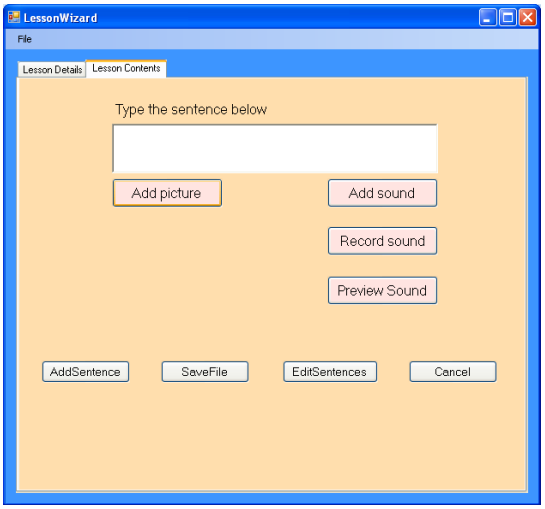


2. Click on File and choose New

3. Complete the lesson details as follows:
   Sentence completion:
   If there is one missing word then number of wheels is one, if there are two missing words then number of wheels is two.
   SpotWord:
   Always has one wheel
   WordReading:
   Always has zero wheels

Spelling:
The number of wheels depends on the number of syllables in the word, for example, i[ma]li has one wheel and u[no]do[li] has two wheels.
Each lesson file should have a consistent number of wheels.
Select the language of the lesson
Select the type of lesson

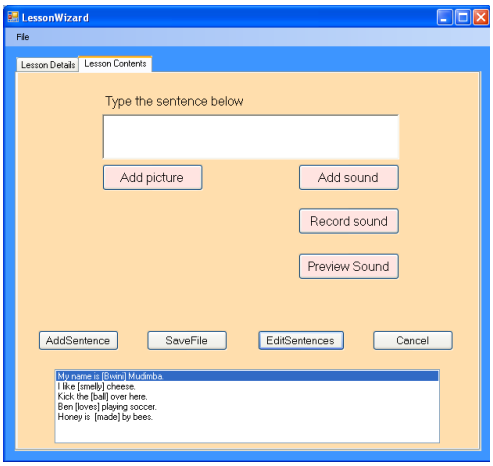
4. Click on **Submit**



5. In the empty text box, type your text as follows:
   Spelling:
   i[se]le for one wheel
   u[no]po[pi] for two wheels
   WordReading:
   Imali
   Idada etc
   SentenceCompletion:
   UFezile soloko ezoba [indlu] nemoto. For one wheel
   ULizeka [uzoba] [iibhokhwe] namatakane. For two wheels
   SpotWord:
   Ikati; inja; idonki; [igusha]
6. Click on **Add Picture** to choose a picture from the gallery
7. Click on **Add Sound** to choose a sound file from the gallery
8. Click on **Record Sound** to record your own sound
9. Click on **Preview Sound** to listen to the chosen sound
10. Click on **AddSentence**
11. Repeat step 5-10 for all sentences in the lesson
12. Click on **SaveFile** to save your lessons as follows:
    Spelling:
    IsiXhosaSpellX with X representing the difficulty level in ascending order
    WordReading:
    IsiXhosaWordsX with X representing the difficulty level in ascending order
    SentenceCompletion:
    IsiXhosaSentencesX with X representing the difficulty level in ascending order
    SpotWord:
    IsiXhosaSpotWordLevelX with X representing the difficulty level in ascending order

Steps to edit a lesson

1. Open the lesson author
2. Click on File, Edit
3. Choose the lesson to edit from the list and click on Open
4. Click on the Lesson Contents tab
5. Click the EditSentences button



6. A list of all sentences in the file will appear
7. Right click on the sentence you want to edit and select either edit or delete depending on what you want to do
8. If you select edit, a sentence editor will open up where you can change the picture, sound file or the text