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Technology For Improving Early Reading In Multilingual Settings: Evidence From Rural South Africa

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Abstract

In September 2015, the United Nations ratified 17 Sustainable Development Goals (SDGs), including a central goal to improve the quality of learning, and attain universal literacy. As part of this effort, the UN and other funding agencies see technology as a major enabling tool for achievement of the SDGs. However, little evidence exists concerning major claims about the success of particular interventions, especially in developing countries. An additional barrier to achieving the SDGs for education is a better understanding of how learning occurs for promoting successful transfer of reading skills in linguistically diverse settings.

This research investigates the impact of a computer-based early grade reading intervention for improving literacy outcomes in rural South Africa. Results show that learners in intervention schools performed significantly better on mother tongue reading fluency measures, as well as comprehension. Further, this study identified a pair of values by which mother tongue decoding skills significantly improved the ability to predict transfer of skills to English.

The findings indicate that teaching literacy through guided and contextualized digital material can support development of early reading skills. However, more research is needed to enhance sustainability of the treatment effect over time. The results further demonstrate the importance of establishing baseline reading skills in a mother tongue language for improving transfer of literacy skills to English.

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TECHNOLOGY FOR IMPROVING EARLY READING IN MULTI-LINGUAL SETTINGS:
EVIDENCE FROM RURAL SOUTH AFRICA

Nathan M. Castillo

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TECHNOLOGY FOR IMPROVING EARLY READING IN MULTI-LINGUAL SETTINGS:
EVIDENCE FROM RURAL SOUTH AFRICA

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2017

Nathan Matthew Castillo

To my family, with a full and gracious heart

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ABSTRACT

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Nathan M. Castillo

Daniel A. Wagner

In September 2015, the United Nations ratified 17 Sustainable Development Goals (SDGs), including a central goal to improve the quality of learning, and attain universal literacy. As part of this effort, the UN and other funding agencies see technology as a major enabling tool for achievement of the SDGs. However, little evidence exists concerning major claims about the success of particular interventions, especially in developing countries. An additional barrier to achieving the SDGs for education is a better understanding of how learning occurs for promoting successful transfer of reading skills in linguistically diverse settings.

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The findings indicate that teaching literacy through guided and contextualized digital material can support development of early reading skills. However, more

research is needed to enhance sustainability of the treatment effect over time. The results further demonstrate the importance of establishing baseline reading skills in a mother tongue language for improving transfer of literacy skills to English.

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LIST OF ABBREVIATIONS

ABET	Adult Basic Education and Training
ACR	All Children Reading
ANA	Annual National Assessment
BFI	Bridges to the Future Initiative
BICS	Basic Interpersonal Communicative Skills
BYOD	Bring Your Own Device
CAL	Computer Assisted Learning
CALP	Cognitive/Academic Language Proficiency
CAPS	Curriculum and Assessment Policy Statement
CUP	Common Underlying Proficiency
CWRPM	Correct Words Read per Minute
DID	Difference in Difference
EFAL	English as a First Additional Language
EGRA	Early Grade Reading Assessment
FE	Fixed Effects
FIML	Full Information Maximum Likelihood
ICTs	Information and Communication Technologies
L1	Literacy 1: Mother tongue (Sepedi, Tshivenda, Xitsonga)
L2	Literacy 2: English
LDoE	Limpopo Department of Education

LMICs	Low and Middle-Income Countries
LoLT	Language of Learning and Teaching
NCS	National Curriculum Statement
NRS	National Reading Strategy
NRS	National Reading Strategy
ORF	Oral Reading Fluency
R1	Research Question 1
R2	Research Question 2
RCT	Randomized Controlled Trial
SACMEQ	The Southern and Eastern Africa Consortium for Monitoring Educational Quality
SDGs	Sustainable Development Goals
USAID	United States Agency for International Development
ZPD	Zone of Proximal Development

1. Introduction

In September 2015, 193 countries of the UN ratified 17 Sustainable Development Goals (SDGs), including a central goal to improve the quality of learning, and attain universal literacy. As part of this effort, the UN and other funding agencies see technology as a major enabling tool for achieving these SDGs. Yet, relatively little solid evidence exists concerning the claims about the impact of information and communications technologies (ICTs) on promoting learning and literacy in low-income countries. The following study seeks to build on the existing literature along two modes of inquiry. The first aspect of the study investigates the impact of a technology-enabled intervention for improving early literacy skills in primary schools across linguistically diverse contexts of South Africa. The second aspect analyzes whether there is a distinct correlation in the transfer of early literacy skills to a first additional language.

Problem Statement and Contextual Factors Motivating this Study

Decades of oppression and segregation prior to and reinforced through the Apartheid regime in South Africa have created a legacy of unequal schooling throughout the country. At the heart of the policy for educating Black South Africans, the Bantu Education Act of 1953 emphasized a compartmentalization of education governed by a body whose purpose was to keep the state-controlled system 'separate and inferior' to that of its White counterparts (South African History Online, n.d.). An artifact of the segregated schooling policy is an inadequate education delivery system. Learning deficiencies are most pronounced in rural and linguistically diverse communities

characterized by limited resources, overcrowded classrooms, and led by under qualified teachers (UNICEF, n.d.).

Recently, negative publicity from international assessments has led to a call for action within the current South African administration. The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SAQMEQ) assesses a variety of reading and numeracy skills in 15 member countries. Findings demonstrated that after 6 years of schooling, 63% of South African learners are not competent in basic reading skills (Moloi & Chetty, 2010). Further, a lack of evaluation at the school level restricts the opportunity for educators to adapt their instruction approach so that learning objectives and pedagogical strategies are tightly aligned (Wagner, 2011). This reality is most apparent in rural, lower-resourced provinces (DBE, 2013).

The Annual National Assessments (ANA) is a yearly examination that tests the ability of learners in grades 1 to 9 and is administered in all public schools serving those grades. Longitudinal results confirm Limpopo Province as one of the poorest performing regions in the country with a widening achievement gap (DBE, 2014). Overall, performance for Limpopo in 2012 was 2 percentage points below the national average; in 2013 the gap widened to 3.6 percentage points; and in 2014 Limpopo performed 6 percentage points below the national average (DBE, 2014).

In 2014, Grade 2 learners in the Limpopo province averaged 55.1% on the Home Language ANA, the second lowest score out of all the provinces only in front of Eastern Cape. In addition, Grade 4 students in Limpopo averaged 36.3% on the English as a First

Additional Language (EFAL) component. This represents the lowest score out of all the provinces for three consecutive years.

Through a concerted effort, overall literacy is improving in South Africa, but certain contextual complexities prevent the marginalized provinces within the country from progressing at the same pace as more developed regions. In particular, mother-tongue instruction remains a serious challenge for ensuring quality learning environments in multilingual settings throughout South Africa (Moloi & Chetty, 2010). Limited teacher capacity compounds deficiencies among struggling learners (DBE, 2008).

Findings consistently point to deficiencies in initial teacher preparation to adequately monitor and adapt instruction for a diversity of learner needs (Strauss, 1999; DBE, 2013). For many students, simple, grade appropriate learning material developed in their home language is unavailable or unclear.

This type of publicity has been instrumental in developing strategies for improving the education delivery system. The National Reading Strategy (NRS) was developed in 2008 to advance literacy objectives and curriculum expectations as informed by a variety of stakeholders (DBE, 2008). Key pillars of the strategy emphasize monitoring of performance, improved teaching methodologies and training support, in addition to resource development through strategic partnerships (2008).

In 2012, the South African Department of Education amended the National Curriculum Statement (NCS) that governs education in the country. With the goal of streamlining implementation, the department established a single document for each

subject (DBE, 2013). This collection of documents is referred to as the Curriculum and Assessment Policy Statements (CAPS). The curriculum statements aim to improve learning in local contexts while enhance accountability through ongoing monitoring of skills.

In addition to policy reforms, several targeted interventions have been adopted to respond to specific objectives of the NRS. Rigorous evaluations of many of the interventions are still underway. Although a major technical limitation of these studies is that they emphasize outputs (training completed, materials delivered, curriculum developed, etc.) instead of outcomes (education quality enhanced, learning improved, etc.). However, developing a deeper understanding of specific outcomes through experimentation with educational inputs is imperative for policy reform to have any real impact on improving learning among rural South African students. The present study attempted a randomized controlled trial (RCT) to measure literacy outcomes in rural South Africa along two lines of inquiry.

R1: Does access to guided, digital reading software in their language of choice improve early literacy outcomes among foundation phase learners in rural South Africa?

The first research question (R1) investigates whether access to quality, digital reading software in their language of choice can improve early literacy outcomes among foundation phase learners. The R1 research hypothesis states that learners engaged in guided use, student-centered literacy software in their language of choice will produce reading scores beyond those of their counterparts.

Underpinning the design of the program is the integration of technology to provide a student-centered approach for complementing early literacy instruction. Incorporated into the software is the ability to specify and augment mother tongue instruction (L1) to instruction in a first additional language (L2). The policy implication of this component of the research is aimed at improving quality learning environments among students in under-resourced settings. The concepts associated with the R1 hypothesis are operationalized as follows:

- a. Guided use. Defined as a clear specification of the target subject, the software to be used, and prescribed schedule of use (Arias Ortiz & Cristia, 2014).
- b. Student-centered. Defined as direct learner engagement with the content and individual responsibility of pace and progression through the curriculum, while teachers play a supportive role.
- c. Literacy software. Defined as the Bridges to the Future Initiative computer-based curriculum for grades 1-3
- d. Language of choice. Defined as one of three local languages (Sepedi, Tshivenda, Xitsonga) and English.
- e. Reading scores. Defined as a set of results from four student-level subcomponents on the Early Grade Reading Assessment (EGRA)
- f. Treatment group. Defined as learners from schools that receive the BFI intervention (n = 5).

- g. Improve beyond. Defined as individual difference scores (endline minus baseline) on the EGRA instrument.
- h. Counterparts. Defined as learners from a set of schools that do not receive the BFI intervention (n = 10).

R2: Does the relationship between reading outcomes in a mother tongue (MT) language and a first additional language change significantly at varying levels of MT proficiency?

Along this second line of inquiry, the hypothesis states that there is a distinguishable cutoff point whereby reading proficiency in a home language substantively improves the ability to predict reading proficiency in a second language. English is the Language of Learning and Teaching (LoLT) in South African schools beginning in Grade 4. Therefore, the EFAL curriculum for Grades 1-3 is important because students must be ready to transition to English-only instruction regardless of their level of proficiency by the end of Grade 3. However, the curriculum statement lacks an empirical benchmark justifying this approach. The analysis aligned with R2 seeks to inform strategies for improving bilingual and multilingual literacy instruction in South Africa with implications for multi-lingual contexts on a broader scale. The concepts associated with the R2 hypothesis are operationalized as follows:

- a. Distinguishable cutoff point. Defined as the approximated point at which the expected slope in reading outcomes between mother tongue and a second language increases substantively upon analysis of a bi-variate scatterplot

with a locally weighted regression model fit to the data.

- b. Reading proficiency. Defined as scores on a subcomponent test of the EGRA instrument.
- c. Home language. Defined as any of the L1 languages: Sepedi, Tshivenda, or Xitsonga.
- d. Substantively improves the ability to predict. Defined by the ability to reject the null hypothesis of no difference in the bi-lingual relationship for reading outcomes when compared at points along the locally weighted model that demonstrate clear departures from a linear fit of the data.
- e. Second language. Defined as English.

Positionality Statement

Given my limitations in language, culture, and background with the communities of interest, my positionality played a significant role in how the data was collected and interpreted for the present study. My role in this research is one of a quasi-external evaluation specialist who was subcontracted to conduct this research through funding provided by my host institution at the University of Pennsylvania. I have also been involved in the proposal development and evolving research design with the implementing organization since 2013.

Since this research involves primary data collection, South African nationals were directly involved in the fieldwork. Further, I relied solely on local enumerators for administering EGRA instruments in languages other than English. Therefore, it is

imperative that I remain clear up front about my role and how that may bias the way the findings are interpreted and reported. To this end, I have collaborated with a team of South African counterparts during the analysis and interpretation phase of the research to mitigate the amount of personal bias that I may bring to the study.

Dissertation Overview

This research is further elaborated along the following chapters. Chapter 2 discusses the relevant literature from the various domains that comprise this study. The focus of this chapter is to clarify the motivation behind the study as it is situated in current theory and recent empirical findings. The emphasis of the review is based on education development in low and middle-income countries (LMICs). Findings from experimental studies related to early literacy, language development, and appropriate use of technology will inform the discussion. Chapter 3 provides a description of the intervention and prescribed implementation plan.

Chapter 4 reviews the methods incorporated into this study including sampling procedures, data collection instruments and analysis approach. This chapter also presents findings from the instrument validation analysis for L1 and L2 instruments. Finally, frequency data with descriptive statistics are provided as a means of illustrating the pair of datasets used for the research respective research questions.

Chapter 5 presents the results from the analysis and is divided into two parts. First, longitudinal results are presented for estimating BFI impact on early reading outcomes in L1. The chapter then presents the results from the correlational analysis on

literacy transfer.

Chapter 6 provides a discussion of the findings while explaining the significance of the results. Chapter 7 concludes with a review of the main findings and implications including limitations of the data and suggestions for future research.

2. Literature Review

Human Development and Learning

Learning is widely accepted as a fundamental human right and has been a focal point of world development goals (United Nations, 2000; UNESCO, 2000; United Nations 2015). Not surprisingly, emphasis from the United Nations has prompted an increase in support to education. It also opened the door to public scrutiny of children's learning on a global scale. Through these efforts, enrollment has expanded greatly (UIS, 2011), and especially for girls (UNESCO, 2012). There is also a broad body of literature demonstrating the far-reaching and positive effects of schooling on wages (Card, 2010), employability (Sporh, 2003), child mortality (Chou et al., 2007), preventing early pregnancy (Baird et al., 2009; Ozier, 2010), and many other non-education development goals (UNESCO, 2013).

However, unintended consequence of getting more children into school has placed new constraints on education systems and their ability to deliver positive learning environments (Wagner et al., 2012). New studies illuminate this reality in terms of low literacy acquisition (Gove & Cvelich, 2010) and grade completion (World Bank, 2011) where poor and marginalized learners are the most affected (Reimers, 2000; Holsinger, 2005; Zhan, 2006). These realities have generated a renewed effort in understanding sociocultural dimensions associated with learning, particularly in developing countries (Robinson, 2011; World Bank, 2011; Wagner, 2014).

While many factors interact with learning development, the study of culture on

cognition is a prominent dimension within contemporary research. Culture is described as a cumulative but iterative process of shared practices, beliefs and artifacts as mutually interpreted by a group (Greenfield et al., 2003). Among contemporary cognitive research, two prominent perspectives emerge to describe the mechanisms of cultural influence on human learning.

Bronfenbrenner's ecological systems theory describes five distinct and concentric environmental systems by which an individual's psychological development is influenced (1979). Within this approach, the microsystem is closest to the individual (for example: home & school), and thus, the most influential system. An individual's interaction with each distinct system establishes roles, norms and rules that shape their development. The magnitude of developmental influence decreases as systems increase in distance from the individual. An underlying characteristic of this model is that attitudes and ideologies about culture that serve to guide socialization and developmental processes are oriented within the most distal, macro-level context (Bronfenbrenner & Morris, 2006).

Alternatively, the cultural-historical perspective describes an internalization of symbolic systems (such as language and literacy) with cultural values to assert a direct link between sociocultural influences on the development of higher psychological functioning (Luria, 1976; Vygotsky, 1978). As the name suggests, the cultural-historical perspective establishes culture and social interaction in a central role for the development of complex thinking. This is contrary to the ecological systems theory

where culture is isolated to the outermost system implying a weaker level of influence on psychological development.

An influential concept in educational psychology attributed to the cultural-historical perspective is referred to as the Zone of Proximal Development (ZPD). This concept connects his psychological perspective with pedagogy to describe the internal learning process that takes place through collaboration with adults or peers in order to develop higher, independent cognitive functions (Hedegaard, 2012). This approach describes traditional instruction and learning across a variety of settings and has been a focal point of experimentation in diverse applications around the world.

Literacy Acquisition

Literacy is a fundamental skill for lifelong learning and is correlated with a number of positive human development indicators (Levy & Murnane, 2001; Schleicher, 2010). Deficiency in reading ability is among the most prominent predictors of future disadvantage in terms of educational, social, and economic outcomes (Tamim et al., 2011; Bradley & Putnick, 2012; UNESCO/BREDA, 2005; Levy & Murnane, 2004). Given its extension to all other areas of learning, reading is the most critical indicator of the quality of early grade education and is the core subject matter in schools around the world (Wagner, 2014).

Defining literacy extends beyond reading and combines research from an interdisciplinary perspective (Wagner, 1993; 2010). Specific classification of literacy is complex and necessarily fragmented, but a universal assumption is that literacy involves

the process of arriving at the meaning of a written text and applying cognitive tasks to communicate through a shared discourse (Wagner et al., 1999; Snow & RAND, 2002). Literate behaviors involve creative and analytical acts such as producing text through writing and a display of knowledge along specific subject matter domains (Anderson & Pearson, 1984).

Universal to reading is the effective integration of orthographic, phonological, and semantic information (Perfetti, 1985). However, reading acquisition develops through increasing stages of proficiency that build in complexity from early stages of learning-to-read to the integration of higher-level cognitive skills for reading-to-learn (Chall, 1996).

Stage	Approximate Age/Grade	Characteristics by End of Stage
0: Pre-reading	6 months – 6 years Preschool	Child “pretends” to read when holding book, can cite letters of alphabet, prints own name.
1: Initial reading & decoding	6 – 7 years Grade 1 – Early Grade 2	Child learns relation between letters and sounds in printed text and spoken word, can read simple text with phonically regular words, can sound out new, short words.
2: Confirmation & fluency	7 – 8 years Grade 2 – Grade 3	Child reads simple selections of connected text with increasing fluency.

Table 1. Chall’s stages of early grade reading development for English. Adapted from Chall (1996).

Each stage of reading development requires different approaches to establish mastery of skills. The capacity for children to learn emergent strategies for reading is largely dependent on the type of literacy environments they experience at home, prior to schooling (Peterson, 1994; Wagner, 2011). Children who become successful readers tend to be exposed to opportunities for developing sensory, perceptual, cognitive and social skills early and often (Snow et al., 1998). These pre-school experiences help form children's early concepts about literacy that lead to more complex mental processing over time (Sulzby & Teale, 1991).

The transition from the home environment to formal schooling marks the acquisition of real reading involving changes in the composition of skills for literacy but also in the concepts about the nature of literacy (Chall, 1983). Children coming from poor literacy environments or whose experiences and language interactions do not closely resemble what goes on in the classroom will have a more difficult transition to real reading (Snow et al., 1998; Cummins, 2000). Some obstacles to developing early reading skills include difficulty understanding basic principles in letter/sound association, failure to transfer comprehension skills from speech to text, or low motivation (Snow et al., 1998).

One prominent theory underscores the importance of oral language comprehension and decoding ability for reading development (Gough & Tunmer, 1986). This Simple View of Reading theory was the basis of the report from the National Reading Panel that delineated five component skills for successful reading including

phonological awareness, decoding, vocabulary knowledge, oral reading fluency, and comprehension (NICHD, 2000). Since these componential stages of reading acquisition are understood to build on each other, proficiency in lower-order skills can be predictive of later reading achievement (RTI International, 2015).

While some processes of reading development are universal, other aspects differ based on variations in non-alphabetic orthographies that limited adherence to the phonics approach. Therefore, some scholars have criticized the limited applicability of theories like the Simple View of Reading citing an over influence on the alphabetic orthography of the English language (Zeigler et al., 1996; Seymour et al., 2003). As a result, researchers are developing new ways of knowing about how reading is developed through alternative, non-alphabetic orthographies (AIR, 2014; Frost, 2005; Perfetti et al., 2005; Seymour, 2006; Ziegler & Goswami, 2005).

Most of what is understood about literacy is oriented within the perspective of formal learning and schooling. Alternatively, Wagner (2010) contributes a cultural interpretation of literacy developed largely by non-formal interactions with text (such as with religious text) and other experiences influenced from outside of the classroom. This notion builds on earlier research oriented toward understanding social practices of literacy beyond economic or cognitive outcomes (Scribner & Cole, 1981).

Others have extended this perspective through ethnographic studies to establish a pluralistic concept of literacy that distinguishes sociocultural interpretations from the more traditional interpretation of literacy as a measurable set of cognitive skills (Street,

1984; Street, 1999; Martin-Jones & Jones, 2000). This “multiple-literacies” perspective is openly critical of literacy testing as a measurable (and dichotomous) outcome variable as it has been seen to negatively bias ethno-linguistic minority groups (Wagner, 2011; Pratham, 2010). Therefore, some claim that meanings and pedagogical practices related to literacy should necessarily be contested to offset oppressive and marginalizing agendas (Freire, 1981; Street, 2001).

Language and Literacy

Despite impressive expansion in access and enrollment of children, international research has shown that many schools fail to support literacy development even after several years of schooling (EdData, 2004; Abadzi, 2008; Gove & Cvelich, 2010; RTI International, 2015). Challenges to literacy development are not surprising. Reading acquisition is a dynamic phenomenon where demographic characteristics such as language, gender, and geography help to explain large disparities in literacy across and within countries (Wagner et al., 2016).

Recent estimates indicate that more than one-third of children around the world are not learning basic literacy skills in their classrooms (Perlman et al., 2016). In South Africa, findings reveal that over 60% of learners are not competent in basic reading skills after 6 years of schooling (Moloi & Chetty, 2010). Limited exposure to quality learning environments has disproportionately impacted language learners and rural students in terms of poor reading performance (Gove & Cvelich, 2010; ASER, 2014). The growing achievement gap created by early learning deficiencies between developed and

developing countries continues to push the universal literacy agenda further out of reach (Winthrop & McGivney, 2015).

Language of instruction plays a prominent role in literacy acquisition, especially within multilingual settings. Evidence shows that in many developing country contexts, there is a misalignment of the language spoken at home and the official language of instruction in formal school settings (Ball, 2010). In these contexts, teachers are usually inadequately prepared to respond to such diversity in learner needs (Ball et al., 2014). Research promoting mother tongue literacy instruction has prompted new policies to support full proficiency in home language before learning to read in a first additional language (Pinnock, 2009; Cummins, 1981; Cortina, 2014). The research leading to these policy shifts were largely informed by early work from scholarship on mother tongue instruction.

Oller (1978) first presented the idea of a “global language proficiency factor” for explaining the much of the variation in language proficiency measures related to academic achievement. However, Cummins (1980) contends that instead of one global factor, there are two distinct dimensions of language development. The dimension that language learners develop first is referred to as basic interpersonal communicative skills (BICS) (1980). Features of BICS proficiency are best described by in-person conversational skills developed through highly contextualized situations. Cummins refers to the second dimension as cognitive/academic language proficiency (CALP) (1980). This deeper dimension of language proficiency requires more time to develop

and is associated with literacy and other decontextualized cognitive tasks (1980).

Prior to this point, little was known about the relationship between the development of L1 proficiency on a first additional language (Wagner, 1993). To further investigate this linguistic interdependence, Cummins (1979) presents a pair of theories for describing the importance of adequately developing both L1 and L2 to fully access the benefits of bilingualism. First, his threshold theory contends that a minimum level of bilingual competence is necessary to positively influence cognitive growth (1979). Cummins further describes a dual threshold effect whereby a lower threshold level of bilingual competence would help to avoid negative cognitive effects while a higher threshold level could lead to enhanced cognitive functioning (1979).

While this threshold theory is important for providing a framework for predicting learning outcomes at different levels of bilingual competence, it is limited in its ability to describe the transfer of skills within a bilingual context. Therefore, Cummins proposed the developmental interdependence theory (Cummins, 1979). This theory states that the level of L2 competence a bilingual child attains is a function of their L1 competence at the time exposure to the first additional language begins (1979). This interdependence theory is the foundation for Cummins' common underlying proficiency (CUP) model or the dual-iceberg model as it is commonly referenced.

According to the dual-iceberg model, there is a common proficiency that determines academic performance on tasks such as reading despite the visibly distinguishable surface features between two given languages (such as phonology,

syntax, and lexicon) (Cummins, 1980). This model also accounts for underlying aspects of proficiency that are unique to each language that may not be associated with CALP. Figure 1 depicts an illustration of these concepts taken together. While Cummins research continues to be widely used within the domain of bilingual literacy, recent studies have expanded biliteracy research to investigate linguistic interdependence from alphabetic to non-alphabetic languages common in Asian contexts (see Reddy & Koda, 2013; AIR, 2014).

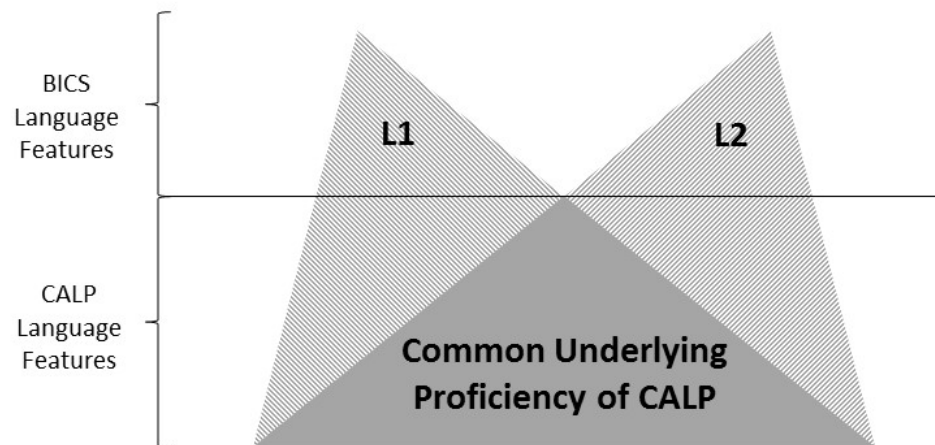


Figure 1. The Dual-Iceberg Model of Bilingual Proficiency. Adapted from Cummins (1980).

Equally important for improving literacy is developing curricula that actively engages learners and aligns with contexts that are culturally relevant to them (Ball et al., 2014). Recently, more experimentation with student-centered literacy programs and user generated reading materials is producing positive results, especially within the

domain of information and communication technologies (ICTs) (Ridell, 2001; Aderinoye & Rogers, 2005; Wagner et al., 2010).

ICTs and Performance

Advances in speed, and coverage of ICTs have led to innovative approaches for promoting literacy acquisition. Further, rapidly decreasing costs of ICTs, even in developing countries, have generated interest in their potential to enhance 21st century modes of inquiry (Donner, 2008; Collins & Halverson, 2009; McKinsey, 2012).

Distinct advantages of ICTs are their ability to adapt curricula to locally relevant contexts, languages, and learner pace. Central to successful ICT design for deployment in marginalized settings is a “pro-poor” approach (Unwin, 2004) that emphasizes content relevant to user needs, skills, and motivation for learning (Geldoff, 2009; UNESCO, 2010). Also, leveraging existing technology as opposed to importing foreign devices can have a positive impact on sustainability (DeBoer, 2009).

Research in the United Kingdom provides evidence in support of the enabling effect of integrating technology across a range of outcomes for children and youth (Underwood, 2009). However, other studies have demonstrated mixed results and even negative effects of treatments with computers or technology (McEwan, 2015; Bulman & Fairlie, 2015). Limitations of existing research on ICTs reveal that much of the evidence is concentrated in either western (well-resourced) contexts or very specific “pilot” settings that limit the comparability of findings (Hinostroza et al., 2014).

Despite increases in investment (WITSA, 2010) and coverage (ITU, 2015) serious

challenges remain in understanding particular uses of ICTs and learning with computers for enhancing performance. Much of the challenge is related to the breadth in design and purpose through which technology enabled interventions are deployed. Results also vary by country context further complicating comparisons across regions.

A number of frameworks have been developed to orient distinct approaches and offer clarity within an otherwise variegated domain of ICT enabled interventions for improving literacy. Wagner et al. (2014) was one of the first bodies of literature to conceptualize an effectiveness framework for improving ICT program development and implementation for education planning. Within this framework, intervention purposes overlap with appropriate technologies and intended end-users in concentric circles to develop a design solution approach.

Informed by a review of 51 projects worldwide, this framework describes six primary purposes for ICT deployment with learning. Formal learning and instruction is the most intentional purpose and is characterized by guided inquiry through clearly planned learning objectives. Very little research has been conducted in developing countries with this particular purpose.

Alternatively, projects with informal learning purposes deliver non-directed content for consumption outside of or complementary to formal school settings. Much of the existing research in developing countries has deployed a variation of this purpose, primarily applications designed for low-cost cellular devices or handheld readers and laptops with preloaded content.

Interventions designed with content as a main purpose encompass a large group of projects whose goal is to improve access to learning materials in general. What distinguishes this approach from the informal learning approach is a focus primarily on software development that the user must access using their devices.

Training-purposed interventions use guided instruction through digital content for individuals who serve as intermediaries for others' learning. Content is not intended for student-use and generally incorporates applications for introducing or reinforcing pedagogical strategies for improving classroom learning.

Another subset of interventions is designed for data collection to improve monitoring and accountability in education planning through more opportune feedback methods. Often, ICT interventions intended for data collection purposes incorporate applications for monitoring and timely reporting on student progress along a set of pre-specified skills.

Finally, a variety of interventions seek to leverage multimedia to support communication through social networking or information exchange (Wagner et al., 2014). Generally, these interventions are deployed outside of the school setting and serve as a means of supporting outreach and inclusivity.

As particular purposes or combinations of purposes intersect with intended end-users and appropriate devices, a variety of program designs are developed. When context is applied to each component of the framework, these interventions form a *design solution* approach for research and implementation (Wagner et al., 2014). See

Figure 1 below for an illustration of the framework.

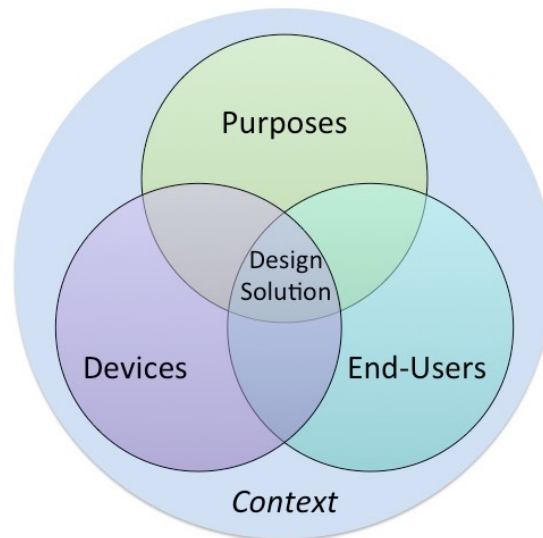


Figure 2. Wagner et al. (2014) Design Solution Framework.

A meta-analysis of fifteen ICT-enabled experiments in low-income countries presents a concept for analyzing results of technology in education (Arias Ortiz & Cristia, 2014). Within this results-based framework, the emphasis is on the logical chain through which a program produces impact along a variety of skills (academic, digital, or general). According to the authors, resources used to provide guided, in-school support consistently produced better learning outcomes over unguided use across a variety of grades and subjects (2014). However, the dispersion of outcomes was greater than the unguided use interventions signaling a need for a more nuanced investigation of ICT use for improving learning. A more contextualized understanding regarding the tradeoff of technology integration over traditional instruction will have important policy

implications.

A growing body of evidence offers insight regarding such a tradeoff in investments in low-income countries. As can be seen from the literature, variations along the frameworks mentioned above have serious implications for outcomes associated with ICT enabled interventions. However, while increasing in prevalence, few empirical evaluations exist in developing country contexts investigating the use of technology on student performance.

Device Centered, Unguided Software: In School and at Home

Cristia et al. (2014) examined the longitudinal impact of a program that provided ICT hardware to a set of schools throughout Peru loaded with unguided software. They found no effect of the program on repetition, dropout or enrollment (2014). An earlier Peruvian study of one-to-one classroom computing also found no impact on student achievement (Cristia et al., 2012).

In Colombia, a similar intervention provided 100 schools with computers without guided software. Distinct from Peru, the Colombia program also included a teacher-training component for educational computer use. A study by Barrera-Osorio and Linden (2009) found null results on improved achievement in the intended subject area. In fact, survey results revealed that teachers did not incorporate the computers into their curriculum despite the additional training.

Beuermann et al. (2013) provides evidence on the impact of one-to-one computing for use in 1,000 homes across Peru. Despite government-endorsed content

loaded onto the devices, the evaluation revealed null results in both math and language achievement (2013). In China, Mo et al. evaluated a home-based intervention that paired interactive content on laptops with training targeted at the students and their parents (2012). Findings showed limited math achievement, but no impact on language (2012).

These studies underscore the importance of a design solution approach that positions technology as one component within a broader framework instead of focusing on the device as the solution (Wagner et al., 2014). A general limitation of existing literature (including the sources cited) is a careful account of the intended ICT-use for supplementing instruction as well as an analysis of fidelity to implementation.

Purpose-driven through Guided Software: In School

Alternative to unguided use, guided instruction implies the use of specific software carefully aligned to the curriculum along a prescribed schedule. Within this domain, results are generally more positive than with unguided use (Arias & Cristia, 2014). However, mixed evidence indicates that characteristics of the intervention are important for detecting impact. Bulman and Fairlie (2015) find that evidence of positive effects among guided ICT interventions are strongest in developing countries due to their ability to substitute lower-quality instruction.

An important study conducted in India showed a significant impact on math achievement through a lab-based intervention that provided supplemental instruction combined with additional class time (Banerjee et al., 2007). However, results of the

earlier study were contradicted once the combined effects of the hybrid model were separated into distinct experiments (Linden, 2008). The follow up study also found significant depreciation in the intervention effect on achievement in subsequent years (2008). The author cites issues related to software functioning as well as the classroom context being substituted as important considerations when evaluating interventions.

In Ecuador, adaptive lab-based learning software was introduced across a sample of schools to complement classroom instruction in the fifth grade. Evaluation findings showed positive gains on math achievement but no effect on language scores given three hours per week of individualized content (Carrillo et al., 2010). Similar results were found in China across multiple studies where positive and significant impacts were observed in math but not language achievement given two 40-minute sessions per week (Lai et al., 2011; 2012a; 2012b; Mo et al., 2013). The China studies were unique in the level of curriculum alignment and support that students were given by dedicated lab coordinators.

This review of randomized interventions in developing countries shows mixed results along intended purpose, actual use, and physical setting. Individualized and guided software with contextually relevant content is likely to be the most effective approach for improving student performance. McEwan (2015) provides evidence of higher average effect sizes among ICT interventions in primary schools as compared to other types of inputs. However, he is cautious about making comparisons without considering cost.

Despite a growing body of literature, some key research questions remain regarding ICT integration in developing country contexts. Some issues include the applicability among diverse populations in terms of language and learning style as well differences across initial achievement. From a policy perspective, identifying how ICTs can produce quality-learning opportunities and be scalable is of particular interest to researchers, governmental agencies and the United Nations.

The implications for literacy acquisition (across multiple interpretations and applications) are profound. However, reading is a complex challenge that interacts with many other developmental skills (Snow et al., 1998). Persistent and pervasive illiteracy rates prove that more research is needed to explore how children learn to read and how teachers, institutions (and technology) can help. To do so, future efforts must move beyond western-oriented perspectives toward a more contextually relevant approach in an ever-expanding globalized world.

3. Description of the Intervention

Resulting from broad scale disparities across South Africa's education system, several targeted interventions were endorsed to improve low-performing communities. One of these initiatives was the Bridges to the Future Initiative (BFI). BFI is a digital media platform developed to improve early-grade reading skills. The program was developed in the four prominent languages throughout the northern province of South Africa including: Sepedi, Tshivenda, Xitsonga, and English. Initial capital for the program was provided through a technology innovation grant issued through the United States Agency for International Development's (USAID) All Children Reading Program (ACR).

The main objective of BFI was to investigate the impact of a computer based literacy intervention on foundation phase learners across Limpopo Province.

The following components comprise the theory of change that informs the BFI strategy:

- If learners have access to interactive activities in their language of choice with immediate feedback on performance in core areas of literacy acquisition, and
- If teachers and are provided with adequate training in the appropriate use of ICT for education, and
- If school administrators promote a learning environment focused on accountability, then foundation learners will gain the skills required to manipulate phonemes, words and sentences to achieve meaning in both

mother tongue and additional languages studied, which will improve learners' literacy achievement to reach or exceed the national average for that grade level.

The original proposal for BFI took shape after pilot testing with early grade learners using the Adult Basic Education and Training (ABET) version of the BFI program. The conceptual framework of both versions of the program (ABET and BFI) contains five elements:

- a) Adapted to local culture. Learning modules are designed within the context of the learners' everyday settings.
- b) Ease of use for the learner audience. The BFI program builds on basic computer literacy skills with animations that guide the learner through each module.
- c) Language choice. The BFI program offers learners a choice of completing the modules in either one of three local languages or English.
- d) Self-paced, computer-based learning. Interactive multimedia enables the learner to hear, identify and manipulate phonemes, which aims to promote motivation and persistence through the program. Since learner progress through the modules at their own pace, learning is contextualized to the user experience.
- e) Teacher empowerment. The intention of BFI is to complement teacher instruction instead of replacing their literacy lessons. Therefore, the modules

are carefully aligned with the national standards for literacy and teachers incorporate the program into their own lessons as an additional tool for improving early grade reading among their learners.

One additional element was added to the BFI program, which was not included explicitly in the previous iteration, namely:

- f. Continuous assessment and feedback. Learners are provided with immediate feedback and correction in the case of response error.

The original concept of BFI was adaptation of the 30 ABET lessons to fit grade 1 learners, based on the successful use of the program in foundation phase trials. However, a review of the ABET lessons by the Molteno development division yielded the following points:

- The content of the ABET lessons was not all contextually relevant and included, for example, lesson topics such as looking for work or university applications;
- The activities included in the ABET lessons could be presented in more appealing ways to early grade learners.

The final early grade BFI program contains 40 lessons: ten for grade one, fifteen for grade two and fifteen for grade three. Lessons adhere to research-based best practice of early literacy components (for reviews, see August & Shanahan, 2006; Wolf, 2008; UNESCO, 2014) and are comprised of the following elements:

- Audio-visual element. Learners first listen to a short story and watch an

accompanying animation orienting them to the lesson.

- Phonemic awareness and phonics. BFI contains several exercises focused on identification of sounds, including phoneme identification and word building.
- Word Building. BFI gives learners opportunities to build up and break down words through typing exercises, games, presentation of examples, and other interactive exercises.
- Grammar and punctuation. BFI also includes elements that focus on grammar and punctuation, including identifying simple parts of speech, application of punctuation, and sentence building.
- Comprehension. Each lesson includes a short story for reading practice and three or four accompanying comprehension questions.
- Writing and Speaking Exercises. In addition to troubleshooting and an introduction to the program, BFI teacher guides provide lesson summaries for each lesson and writing and/or speaking exercises at beginner, intermediate and advanced levels. These exercises include activities such as: discussing reactions, impressions or ideas; drawing and sketching exercises; completing words; matching pictures; ordering sentences; word and sentence writing; completing forms; and free writing activities. Teachers can therefore bridge between the program and classroom activities.

Each multimedia activity includes an oral explanation of the proceeding activity, the activity itself, and feedback based on the learner's response.

Program Development

BFI applies a culturally appropriate, phonics-based approach to support early literacy instruction. The software incorporates interactive activities to reinforce letter-sound recognition, and phonemic awareness, as well as sentence construction and whole-text reading. Working in three indigenous African languages and English, BFI offers quality learning content to primary school students in their language of choice to develop early literacy and digital literacy skills among historically disadvantaged populations.

Program content was developed in consultation with literacy, software development, and African language experts to ensure linguistic accuracy and contextual relevance. See Appendix A for the BFI lesson structure and activity breakdown by lesson.

The process for BFI content development began with an English draft of each lesson storyline incorporated into the audio-visual element. This was adapted as necessary by foundation phase language teachers, and then reviewed for accuracy by local language editors. The rest of the lessons were built from the basis of these audio-visual components beginning with the construction of reading passages.

Written passages were reviewed with literacy experts by the local partnering organization. For the English passages, a readability score was applied to ensure both appropriateness and developmental difficulty. However, readability scores are less reliable in African languages so a combination of readability scores, overall word count, average words per sentence, and developer and editor comments were all used to

determine difficulty.

Passage drafts were reviewed with translators and language editors, who commented on the linguistic accuracy, overall flow of the language, appropriateness of the story or content to the grade level, and quality of presentation. Upon review, some stories were sent to new developers for editing.

Prior to full rollout and installation, preliminary content was field tested in classrooms in Limpopo. Teachers reviewed the stories for perceived errors, made suggestions, and read the stories aloud to learners, who were asked to answer some questions at the end. This was done in a sample of five schools that were not a part of the official BFI program. Formative evaluation data were collected regarding technical functionality and bugs in the software. Recommendations were then submitted to the software developer for revision.

Observations from field-testing were reviewed in consultation by language experts. Since regional dialects vary language use slightly, multiple options are sometimes considered officially acceptable. Where conflict occurred, edits from language experts were prioritized.

Once all the program content was developed, language editors reviewed the material and additional edits were made before the content was adapted into a multimedia platform. The program was installed at school sites only after an additional satisfactory review of the digital content was completed.

Program Implementation

The program was installed in 50 schools throughout the province identified by the Limpopo Department of Education (LDoE) based on a list of priority characteristics for participation. See Appendix B for the list of criteria used for participation. Initial rollout of implementation took place from April to May of 2014. Preliminary implementation activities included BFI installation, delivery of teacher's guides, and training of teachers at all of the selected sites.

In addition to the installation and training activities, a sample of six schools was identified for evaluation purposes. This number was agreed upon by the funding agency given local capacity to carry out the evaluation. Baseline testing with the Early Grade Reading Assessment (EGRA) within each of these evaluation sites was conducted during midyear of 2014 by a team of local enumerators. Enumerators received a two-day workshop on the administration of EGRA and a program overview prior to rollout. Appendix C provides a full list of the selected evaluation sites. See Appendix D for the English language version of the instrument used as a part of this study.

Of the fifty schools that were originally included in the installation rollout, several schools were identified as being noncompliant with the intervention. Ten sites were randomly assigned from this subset of schools to a control group for comparison purposes. Baseline tests of control schools were administered during midyear of 2014 while endline tests for grade 2 learners only were administered midyear of 2015 across all sites. A third wave of data collection took place from May through August of 2016.

This third wave of data collection included the sample of learners from all evaluation and comparison sites that were successfully tracked from baseline to endline in the previous two waves of data collection (n=215).

Teacher training took place in two stages. The first addressed orientation to the program, use of the teacher guides, use of program hardware/software and troubleshooting. The teachers were then given time to complete a lesson on their own followed by a discussion of their experiences and a question and answer session.

A brief computer literacy component was included in the trainings for teachers with limited to no prior experience working with educational technology. The computer literacy training was limited to the skills and functions necessary to successfully operate the BFI program and included basic mouse operations, opening and closing programs, double clicking and dragging, as well as troubleshooting problems with the hardware and software.

The trainings were conducted in conjunction with the installation schedule and lasted between 1 and 3 hours, depending on the time needed to complete a BFI lesson. On most occasions, learners were invited to practice a BFI lesson while the teachers simulated a classroom instruction session, which provided an in-service training opportunity.

Concurrent to the rollout and in conjunction with teacher training, teachers were provided with guides. The guides included an introduction to the BFI program with basic information on the content and its intended uses. A second element of the guides was

to anticipate functional problems with the software and explanations of how to manage potential technical errors encountered.

A final element of the teacher guides was to provide classroom-based speaking and writing exercises as a follow-up to the BFI lessons. Each lesson had one page of activities including a short summary of the lesson content and topic and two to three activities, which ranged from easy (such as discussing opinions or matching words and pictures) to difficult (free writing). Teachers were encouraged to use these activities to bridge the BFI program for additional practice in writing and speaking. See Appendix E for an example of teachers and students using the BFI program.

4. Methodology

As discussed in Chapter 1, this research focused on two main questions. The first, investigated whether a guided, multilingual digital literacy program could improve reading outcomes in rural South Africa. The hypothesis for R1 stated that students given access to the BFI curriculum would produce larger gains in reading skills than their peers without access to the digital literacy program.

The second research question investigated the presence of a structural break in the correlation reading skills transfer from a mother tongue language to a first additional language. With data collected on each learner in both English and home language, the hypothesis for R2 anticipated that a distinct trend would emerge given a threshold level of mother tongue reading proficiency.

Research Design

R1: BFI Impact. The treatment software for the initial research question was the computer-based Bridges to the Future Initiative (BFI). BFI was designed to complement classroom instruction through a self-paced and remediated learning software.

Therefore, all learners in the study received the normal literacy instruction mandated through the South African government. The analysis incorporated repeated measures data collection over a three-year period. Baseline data was collected in 2014 when the cohort was in grade one. Endline data was collected in 2015 when the original cohort was in grade 2. A one-year follow up was conducted in 2016. The emphasis of the data collection efforts was to follow the same learners over time for longitudinal analysis.

The treatment group was prescribed weekly, 45-minute sessions with the BFI intervention under teacher supervision. At each wave of data collection, individual reading skills were assessed for comparison to a control group. Fidelity to implementation was assessed at endline and follow up among the treatment group using a project-based rubric. Appendix F summarizes fidelity observations at endline assessment by intervention school. In addition to the fidelity to implementation scale, a time on task instrument was developed to track specific learner exposure to the curriculum (Appendix G). However, formative evaluation results showed that the teachers did not effectively administer this instrument. Summaries of classroom observations conducted during endline assessment are included in Appendix H.

The comparison group spent an equal amount of time on an alternative, unguided computer program already installed in their school's computer lab (e.g. Encyclopedia Britannica or similar). The response variables of interest were a set of skills critical for early literacy and include: phonological awareness, decoding, oral reading fluency, and reading comprehension (NICHD, 2000).

The primary independent variable was the treatment condition to which the schools were assigned (BFI or control). Within the treatment variable, dosage was measured at the classroom level. Additional explanatory variables included gender, grade, and school quintile rank. The primary data source for the outcome variables of interest were collected using the Early Grade Reading Assessment (EGRA) (Gove & Wetterberg, 2011).

As discussed in the previous chapter, a total of sixteen evaluation schools were assigned to one of two treatment conditions (BFI or control). The evaluation sites consisted of six treatment schools and ten comparison schools. Group assignment was managed by the local implementation organization. Once assigned to treatment group, a stratified sampling approach was applied to randomly select grade 1 learners at each school site. During 2014 monitoring efforts, one of the treatment schools was dropped from the sample due to noncompliance with the program bringing the total evaluation sample down to five treatment schools and ten comparison schools (n=215).

Hypothesis testing at baseline revealed differences on the outcome variables of interest by group. Unbalanced sampling between groups could have caused the heterogeneity in baseline differences. The treatment group included more than double the sample of the control group selected from about half of the school sites. Therefore, fewer students were randomly selected from across a broader range of control schools resulting in less data capture as compared to the treatment schools. Further investigation showed that school achievement index (quintile level) was likely driving these differences ($\chi^2(2) = 13.9; p = 0.001$). Home language was also identified as significantly different between groups ($\chi^2(2) = 13.8; p = 0.001$).

To reduce sampling bias, the primary research question applied a difference in difference (DID) estimation method with fixed effects fixed at the individual level. This method first subtracts individual scores of the time point of interest from the same individual's score at the T-1 timepoint. The overall mean of the treatment group

difference score is then subtracted from the overall mean of the comparison group difference score to assess BFI impact. This double differencing method is a widely-used technique for accounting for observed heterogeneity at baseline (Allison, 2009).

To account for differences in home language by group, the mother tongue outcome variables were analyzed as a single mother tongue outcome measure. However, since language use is an important aspect of this research results will also be presented on each distinct mother tongue language for exploratory purposes.

R2: Literacy Transfer. The second research question applied multivariate regression with standard errors clustering at the school level. However, since this line of inquiry investigated general correlations without regard to treatment condition, group assignment was not a mediating variable in the model.

To test the literacy transfer hypothesis, the correlational data was analyzed using a three-stage statistical procedure that empirically tested for a relationship between L1/L2 transfer of reading outcomes among learners (AIR, 2014). This three-stage approach first estimated a locally weighted regression model to test the linearity assumption.

Next, bi-variate scatterplots with locally weighted smoothing were produced to examine the linearity of the relationship between variables. An approximated value was identified as the point in mother tongue proficiency above which the English proficiency substantively increased in slope.

Finally, multivariate regressions using clustered standard errors allowed a comparison of the difference in correlations between the target languages below and above the identified value. Formal hypothesis testing analyzing the difference in the relationships was calculated by fitting a fully interacted regression model against a pooled version of the literacy transfer data.

The word reading component of the EGRA instrument was associated with the highest correlation in ORF for both mother tongue and English language, ranging from 0.89 to 0.91 respectively. While the oral reading fluency and comprehension correlation was also high, floor effects significantly reduced the level of analysis along this test component. Therefore, the decoding outcome measure was the focus of the literacy transfer analysis. Given the cross-sectional nature of the data collection approach along this research question, results will be presented in the aggregate as well as at each wave of data collection.

Description of the Datasets

For analysis of both research questions, primary data was collected in South Africa from 2014 – 2016 across each of the study sites. Two datasets were developed corresponding to each line of inquiry. A longitudinal dataset corresponded to the BFI impact on literacy outcomes. This longitudinal dataset consisted of learners who began grade one in 2014 and were tracked at each wave of data collection regardless of grade advancement.

A second correlational dataset corresponds to the investigation into literacy

transfer. This correlational dataset consisted of learners in grades two through four with a recorded EGRA test in both the learner’s mother tongue as well as English. The primary data collection instrument for both datasets gathered information on four components of basic literacy: letter sound recognition, familiar word reading, passage reading, and reading comprehension.

The remainder of this chapter provides further detail about the variables, descriptive statistics and model specification for each of the datasets included in this study.

R1: Longitudinal Dataset Description

The target population for BFI was learners in grades one through three (referred to as “foundation phase” in South Africa) as of 2014. Of this sample, one of the treatment schools was dropped due to lack of compliance with the intervention. Of the remaining learners, only those that were successfully tracked and tested in their mother tongue from baseline to endline were retained in the longitudinal dataset.

Approximately 75% of the sample was successfully located for a third wave of data collection in 2016. The longitudinal dataset represents 645 person-years in three mother tongue languages across fifteen schools.

Oral reading fluency (ORF). Oral reading fluency (ORF) is measured by learners’ proficiency of correct words read per minute (CWRPM). The formula for arriving at the ORF statistic is:

$$\text{ORF} = \frac{\text{Passage Items Correct}}{(\text{60} - \text{Time Remain}) * 60} \quad (1)$$

Equation 1. Oral Reading Fluency

This variable was captured for each of the learners in the longitudinal dataset at baseline (2014), endline (2015) and one-year follow-up (2016). The frequency breakdown for the ORF statistic by year is indicated in the table below.

Year	Total	Treatment	Control
2014	215	150	65
2015	213	148	65
2016	163	118	45

Table 2. ORF (Longitudinal Frequencies)

ORF Difference. ORF Difference was the outcome measure of interest for this study and is a measure of the difference in ORF from the learner’s previous reading fluency score. This dependent variable was used to help control for the baseline differences between treatment groups.

Composite Reading Scores. In addition to the outcome variables discussed above, a composite reading score comprised of mean scores across three EGRA subtasks including letter recognition, familiar word reading, and reading accuracy was also calculated. This composite score represents the ratio of correct responses to total possible correct responses for each of the three subtests. These ratios were then

divided by three to provide an overall picture of students' reading ability on the key reference items.

Treatment. The primary predictor variable was treatment group assignment. This dichotomous variable was coded 1 for treatment and 0 for control. Recorded scores for learners assigned to the treatment group comprised roughly 70% of the longitudinal sample as referenced in the table below.

Group	Observations	Percent
Treatment	450	69%
Control	195	31%
Total	645	100%

Table 3. Distribution by Treatment Group (With Repeated Measures)

Although treatment group assignment was the primary predictor variable of interest, each of the following variables were included in the models as controls for improving model specificity.

Female. This dichotomous predictor variable accounted for variation in outcomes that could be attributed to sex. The group assignment was 1 for female and 0 for male. For the longitudinal sample, the female breakdown was roughly 53% and 51% for the control and treatment groups, respectively. Hypothesis testing for equal variance of gender assignment by group of the overall sample was not significant at the .05 level ($t = 0.40$; $p = 0.69$). Therefore, gender assignment by group did not influence the main

findings of the study. This was similar for each of the respective waves of data collection.

Mother Tongue. There are three distinct languages spoken throughout the region where this study took place. Therefore, an additional categorical covariate was included to account for differences that could be attributed to language. See the table below for a breakdown of language by treatment group. Note that baseline testing revealed significant language differences by group. Therefore, mother tongue outcome variables were analyzed by combining all languages.

Language	Control (Column %)	Treatment (Column %)	Total (Column %)
Sepedi	99 (50)	111 (25)	210 (32)
Tshivenda	33 (17)	153 (34)	186 (29)
Xitsonga	66 (33)	186 (41)	252 (39)
Total	198 (100)	450 (100)	648 (100)

Table 4. Distribution by Language Group (With Repeated Measures)

The coding scheme for the variables included in this study is further described in the table below.

Dependent Variable	Variable Type	Coding
ORF	Ratio	Min: 0.0 Max: 153.96
ORF Difference	Ratio	Min: -33.18 Max: 76
Composite Score	Ratio	Min: 0.0 Max: 1.0
Independent Variables		
Time	Interval	0 Baseline (2014) 1 Endline (2015) 2 Follow-up (2016)
Grade	Ordinal	1 Grade 1 2 Grade 2 3 Grade 3 4 Grade 4
Language	Nominal	1 English 2 Sepedi 3 Tshivenda 4 Xitsonga
Letters	Ratio	Min: 0 Max: 110
Words	Ratio	Min: 0 Max: 50
Comprehension	Ratio	Min: 0 Max: 100
Age	Ratio	Min: 7 Max: 11
Female	Nominal	0 Male 1 Female
Treatment	Nominal	0 Control 1 Treatment
School Quintile	Ordinal	1 Lowest Performing 2 Lower Performing 3 Low Performing

Table 5. Coding Scheme of Variables

Additional Covariates. In addition to the covariates described above, a categorical measure of school quintile ranking was included. Since this program was intended to support learners in the lowest performing school, only schools categorized within the three lowest quintiles were selected for this study. The covariate YEAR was included as a time parameter for the panel analysis with the longitudinal data. GRADE indicates the grade level in which the learner was registered at the time of the respective data collection. LETTERS, WORDS, and COMPREHENSION PERCENTAGE are the three additional components of the EGRA instrument adapted for this study. Descriptive statistics for each of these variables are indicated below.

Predictor Variables		Full Sample (%)	Control (%)	Treatment (%)
Quintile				
	Lowest Performing	22.2	10.6	27.3
	Lower Performing	41.2	57.6	34.0
	Low Performing	36.6	31.8	38.7
Language				
	Sepedi	32.3	49.8	24.7
	Tshivenda	28.8	16.8	34.0
	Xitsonga	39.0	33.5	41.3
Female				
	Male	48.2	47.0	48.7
	Female	51.9	53.0	51.3
Grade				
	Year 1	33.2	36.2	32.0
	Year 2	37.4	39.6	36.5
	Year 3	27.7	24.3	29.1
	Year 4	1.7	0.0	2.4
Year				
	2014	36.13	37.3	35.7
	2015	35.97	37.3	35.4
	2016	27.9	25.4	29.0
Outcome Variables		Full Sample	Control	Treatment
ORF				
	Obs.	593	177	416
	Min.	0.0	0.0	0.0
	Max.	154.0	110.0	154.0
	Mean	23.7	13.2	28.1
	S.D.	27.6	23.1	28.2
ORF Difference				
	Obs.	375	111	264
	Min.	-33.2	-29.0	-33.2
	Max.	76.0	66.0	76.0
	Mean	15.6	14.7	16.0
	S.D.	19.5	19.8	19.4
Composite Score				
	Obs.	592	177	415
	Min.	0.00	0.00	0.00
	Max.	1.00	0.91	1.00
	Mean	0.34	0.21	0.40
	S.D.	0.30	0.25	0.30

Table 6. Summary Statistics of Longitudinal Data

R1 Longitudinal Model Specification

To determine the impact of BFI on early reading outcomes, a fixed effect (FE) model was analyzed on difference scores between the intervention time points (baseline vs. endline). The equation for the two time points are:

$$y_{i1} = \mu_1 + \beta x_{i1} + \gamma z_i + \alpha_i + \varepsilon_{i1}$$

$$y_{i2} = \mu_2 + \beta x_{i2} + \gamma z_i + \alpha_i + \varepsilon_{i2}$$

Subtracting the first equation from the second, yields:

$$y_{i2} - y_{i1} = (\mu_2 - \mu_1) + \beta(x_{i2} - x_{i1}) + (\varepsilon_{i2} - \varepsilon_{i1})$$

Equation 2. Longitudinal Model Specification

Where y_{i1} is the value for the outcome variable of interest for individual i at baseline and y_{i2} is the value for the outcome variable of interest for the same individual at endline. Let z_i be a column vector of variables that describe time invariant characteristics for individuals. Namely, these variables include: LANGUAGE, FEMALE, and QUINTILE. Let x_{it} be a column vector of variables that vary both over individuals and over time from baseline to endline. In the present study, these variables include: TREATMENT, GRADE, and YEAR. The term α_i represents a set of fixed constants for each individual. Finally, the term ε_{it} captures the remaining error not already accounted for in the model. In the combined equation, both γz_i and α_i have been “differenced out”.

R2: Correlational Dataset Description

The second research question was related to literacy transfer and did not rely on longitudinal repeated measurement for the analysis. Therefore, a correlational dataset was developed.

This line of inquiry is informed by the developmental interdependence theory that describes a linguistic relationship between mother tongue language skills and skills in a first additional language (Cummins, 1979). Cummins threshold theory goes on to theorize proficiency levels whereby acquisition of skills in a home language will produce positive cognitive benefits for a first additional language within a bilingual educational context (1980).

The target sample for the correlational analysis included 417 learners across seventeen sites in grades two through four with a recorded EGRA test in both the learner's mother tongue as well as English. For this dataset, three distinct cross-sections of learners were administered the EGRA instrument in both their mother tongue language and English from 2014 to 2016.

R2 Variables

English Decoding. The dependent variable of interest for this analysis was English Decoding and was measured as a ratio of correct words read in English divided by the maximum possible score of 50. Data for this variable was collected using the English language version of the adapted EGRA instrument.

Mother Tongue Decoding. The primary predictor variable was mother tongue decoding and was measured as the ratio of correct words read in mother tongue divided by the maximum possible score of 50. This variable was collected using the local language versions of the adapted EGRA instrument and administered by a team of enumerators proficient in each of the respective South African languages.

Female. The same control for sex was included in this dataset as in the longitudinal dataset. For the correlational sample, female learners represented 52% of the dataset.

Mother tongue. The same nominal variable for local languages used in the longitudinal dataset was included in this correlational dataset. See the table below for a breakdown of language by gender.

Language	Male (Column %)	Female (Column %)	Total (Column %)
Sepedi	43 (21)	42 (20)	85 (20)
Tshivenda	113 (55)	116 (55)	229 (55)
Xitsonga	51 (25)	52 (25)	103 (25)
Total	207 (100)	210 (100)	417 (100)

Table 7. Distribution of Gender by Language Group

Additional Covariates. GRADE indicates the grade level in which the learner was registered at the time of the respective data collection. URBAN is a dichotomous

variable indicating whether the school was located in a rural setting (coded as 0) or in a peri-urban setting (coded as 1).

Descriptive statistics for the outcome and primary predictor variables are included in the table below.

Variable	Full Sample	Male	Female
English Decoding			
n	417	207	210
Min.	0.00	0.00	0.00
Max.	1.00	1.00	1.00
Mean	0.45	0.36	0.53
S.D.	0.34	0.32	0.34
Mother Tongue Decoding			
n	417	207	210
Min.	0.00	0.00	0.00
Max.	1.00	1.00	1.00
Mean	0.53	0.43	0.63
S.D.	0.33	0.32	0.32

Table 8. Summary Statistics of Correlational Data

R2 Correlational Model Specification

To determine the association of literacy transfer to a first additional language, multivariate regression was estimated with robust standard errors clustered by School ID. The model can be expressed in the following form:

$$DecodeEng_{ij} = \beta_0 + \beta_1 DecodeMother_{ij} + \beta_2 Female_{ij} + \beta_3 Grade_{ij} + \beta_4 Urban_{ij} + \varepsilon_i$$

Equation 3. Correlational Model Specification

Where $DecodeEng_i$ represents the observed English language decoding score for individual i . $DecodeMother_i$ represents the mother tongue decoding score for individual i . $Female_i$ represents the gender of individual i , $Grade_i$ represents the learners grade level at time of assessment, $Urban_i$ is a dichotomous variable for school setting, and ε_i captures the random error not included in the model with a mean of 0, constant variance and uncorrelated with the other variables in the model.

Reliability Estimates of Data Collection Instruments

This section presents the reliability scores of the instrument subtasks and the overall language assessments. For empirical analysis, Pearson's bivariate correlations and a Cronbach's alpha test for each subtask by language were produced. These tests were used to determine how strongly the subtasks related to each other and the overall validity of the EGRA instrument. Overall, the four subtasks predicted oral reading fluency well across all language groups, but some subtasks demonstrated a more powerful relationship than others. This is consistent with previous findings for EGRA use in South Africa (Piper, 2009).

English Tool Analysis

Bivariate correlations for the four subtasks included in the BFI version of the EGRA tool are displayed below. The English language instrument analysis applies to the correlational dataset only (R2). All correlations were positive and significant. Word reading and oral reading fluency subtasks were associated with the highest correlation at 0.91. Conversely, the lowest correlation was between letter sound and reading

comprehension at 0.28. Based on these results, all subtasks consistently measured reading fluency well, but the word reading subtask which represented a measure of decoding ability was the strongest predictor of oral reading fluency.

The low correlation between letter sound and comprehension along with the relatively low coefficient on ORF (0.52) indicates that while learners could adequately sound out letters and read connected text in English, they struggled to understand the meaning of what they were reading. However, this could be more evidence of a language barrier rather than deficiency in literacy skills. Reading and writing instruction in English as a First Additional Language (EFAL) is only introduced toward the end of foundation phase instruction, so younger learners may have had minimal interaction with English at the time the assessment was conducted.

Subtask	Letter Sound	Word Reading	ORF	Comp
Letter Sound	1.00			
Word Reading	0.57***	1.00		
ORF Unadjusted	0.52***	0.91***	1.00	
Comprehension	0.28***	0.62***	0.69***	1.00

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 9. Pearson’s Correlations for English Subtasks (Correlational Dataset)

A Cronbach’s alpha reliability test was applied to validate the internal consistency of the English language instrument. Results are presented below with standardized means. All subtasks produced alpha coefficients above the 0.7 threshold associated with highly reliable results. The scale derived from the subtasks on the

English language test appears to be reasonable because the estimated correlation for its ability to measure early reading proficiency is roughly 0.92 ($\sqrt{0.86}$). Based on these data, the instrument worked well for predicting English literacy skills.

However, the result for the letter sound subtask confirms the results produced by the Pearson’s output in that it did not fit as well in the scale. The average interim correlation increases substantially by removing letter sound fluency demonstrating a predicted increase in the alpha coefficient from 0.60 to 0.74. This means that letter sound recognition was not as strong of a predictor of oral reading fluency as the other subtasks. In fact, removing the effect of this subtask altogether would have improved the overall reliability estimate of the instrument. Although, an overall test scale alpha coefficient of 0.86 indicates that this English language version of the instrument was validated as internally consistent.

Subtask	Item-Test Correlation	Item-Rest Correlation	Average Interitem Correlation	Alpha
Letter Sound	0.71	0.50	0.74	0.89
Word Reading	0.93	0.86	0.49	0.75
ORF	0.93	0.87	0.49	0.74
Comprehension	0.77	0.60	0.67	0.86
Test Scale			0.60	0.86

Table 10. Cronbach’s Alpha for English Subtasks Using Standardized Means (Correlational Dataset)

Home Language Tool Analysis

Additional reliability tests were conducted for the home language versions of the EGRA instrument. Analysis of the mother tongue versions of the data collection instrument apply to both the longitudinal dataset (R1) as well as the correlational dataset (R2) and are labeled accordingly throughout the following tables. The first pair of tables presents the results from the bivariate correlations for the instrument subtasks by corresponding dataset. All tasks resulted in positive and statistically significant correlations.

Among the home language instruments, word reading and oral reading fluency were associated with the highest correlation coefficients as was oral reading fluency and reading comprehension. This outcome is consistent with previous research on the strong link between decoding, reading fluency, and comprehension in mother tongue (see RTI International, 2015). Also, correlations between ORF and reading comprehension jumped substantially. This evidence supports the language barrier assumption that the smaller Pearson's correlation on the English instrument may have been an artifact of low exposure to English language material rather than a deficiency in reading skills.

Subtask	Letter Sound	Word Reading	ORF	Comp
Letter Sound	1.00			
Word Reading	0.73***	1.00		
ORF Unadjusted	0.65***	0.91***	1.00	
Comprehension	0.67***	0.88***	0.90***	1.00

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 11. Pearson's Correlations for Mother Tongue Subtasks (Longitudinal Dataset)

Subtask	Letter Sound	Word Reading	ORF	Comp
Letter Sound	1.00			
Word Reading	0.71***	1.00		
ORF Unadjusted	0.60***	0.89***	1.00	
Comprehension	0.60***	0.86***	0.87***	1.00

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 12. Pearson's Correlations for Mother Tongue Subtasks (Correlational Dataset)

Cronbach alpha coefficients for the home language versions of the EGRA instrument were at least 0.89 for each subtask, with an overall alpha of 0.94 and 93 by dataset as displayed in the tables below. These results confirm a high internal validity of the home language instruments for each of the datasets used in the analysis.

Subtask	Item-Test Correlation	Item-Rest Correlation	Average Interitem Correlation	Alpha
Letter Sound	0.83	0.70	0.90	0.96
Word Reading	0.96	0.93	0.74	0.89
ORF Unadjusted	0.94	0.89	0.76	0.91
Comprehension	0.94	0.89	0.76	0.91
Test Scale			0.79	0.94

Table 13. Cronbach's Alpha for Mother Tongue Subtasks using Standardized Means (Longitudinal Dataset)

Subtask	Item-Test Correlation	Item-Rest Correlation	Average Interitem Correlation	Alpha
Letter Sound	0.81	0.67	0.87	0.95
Word Reading	0.96	0.92	0.70	0.87
ORF Unadjusted	0.93	0.87	0.73	0.89
Comprehension	0.92	0.86	0.74	0.89
Test Scale			0.76	0.93

Table 14. Cronbach's Alpha for Mother Tongue Subtasks using Standardized Means (Correlational Dataset)

The following chapter presents the results on both R1 (BFI impact) and R2 (literacy transfer) using each of the datasets described in this section, respectively.

5. Results

R1 Findings: BFI Impact

Research Question 1: Does BFI improve early reading outcomes in rural South Africa?

The following table displays the regression coefficients for the difference in difference (DID) estimates by EGRA subtask, using clustered standard errors. Controls for sex, grade level, and school quintile were included in the models. The table shows that BFI had positive and significant effects on mother tongue reading fluency and comprehension. There were no significant differences between groups for letter sound fluency or familiar word reading.

BFI Year 2 Learners	Letter Sound Fluency (CLPM)	Word Fluency (CWPM)	Oral Reading Fluency (CWPM)	Reading Comprehension (% Correct)
DID Estimates	-3.5	0.2	7.8**	11.0*
(Robust SE)	(3.2)	(1.7)	(2.8)	(4.2)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 15. DID Estimates of Endline BFI Treatment Effects on Mother Tongue Outcome Measures.

In addition to determining the effectiveness of an intervention via a test for statistical significance, it is useful to understand how well an intervention works relative to the comparison group. A widely -used technique for determining this magnitude of difference between two groups is through the calculation of an effect size and reported

as Cohen's *d*. For an independent samples T-test, *d* is calculated as the standardized mean difference between the two groups.

$$Cohen's\ d = \frac{(\Delta M_{BFI} - \Delta M_{control})}{SD_{pooled}}$$

where:

$$SD_{pooled} = \sqrt{\frac{(SD_{control}^2 + SD_{BFI}^2)}{2}}$$

Equation 4. Cohen's *d* Calculation.

Complementary to Cohen's *d*, Glass's *delta* and Hedges' *g* adjustments are also commonly reported. Instead of a pooling the denominator, Glass's *delta* uses only the control group's standard deviation in determining the effect size calculation. This is most useful when the standard deviations between groups are different or the population standard deviation is unknown. Alternatively, Hedges' *g* incorporates a weighted adjustment according to the relative size of each sample. All three calculations are provided in tables below for oral reading fluency and reading comprehension, respectively.

	Control	BFI
ORF Mean (<i>M</i>)	10.3	18.1
Standard deviation	18.7	20.4
Sample size	66	148

	SD calculation	Statistic
Cohen's <i>d</i>	19.6	0.40
Glass's <i>delta</i>	18.7	0.42
Hedges' <i>g</i>	19.9	0.39

Table 16. Effect Size Calculations for Oral Reading Fluency.

	Control	BFI
Comprehension Mean (<i>M</i>)	11.5	22.6
Standard deviation	27.4	31.3
Sample size	66	148

	SD calculation	Statistic
Cohen's <i>d</i>	29.4	0.38
Glass's <i>delta</i>	27.4	0.41
Hedges' <i>g</i>	30.2	0.37

Table 17. Effect Size Calculations for Reading Comprehension.

The figure below illustrates the individual gain scores by EGRA component in 2015. Outcomes were associated with a significant and positive increase in mother tongue literacy (as measured by EGRA) among learners in treatment schools in 2015 (Hedges' $g = 0.39$, $t(135.5) = 2.74$, $p = 0.01$). An effect size of this magnitude can be associated with an increase in ORF gains by almost eight correct words per minute (CWPM) over the counterfactual.

For reading comprehension, the outcomes were also significant and positive among BFI learners (Hedges' $g = 0.37$, $t(141.5) = 2.60$, $p = 0.01$). An effect size of this magnitude can be associated with double the gains in comprehension over the counterfactual (as measured by proportion answered correct on the EGRA reading comprehension component). The following figure illustrates the data across all EGRA components in 2015.

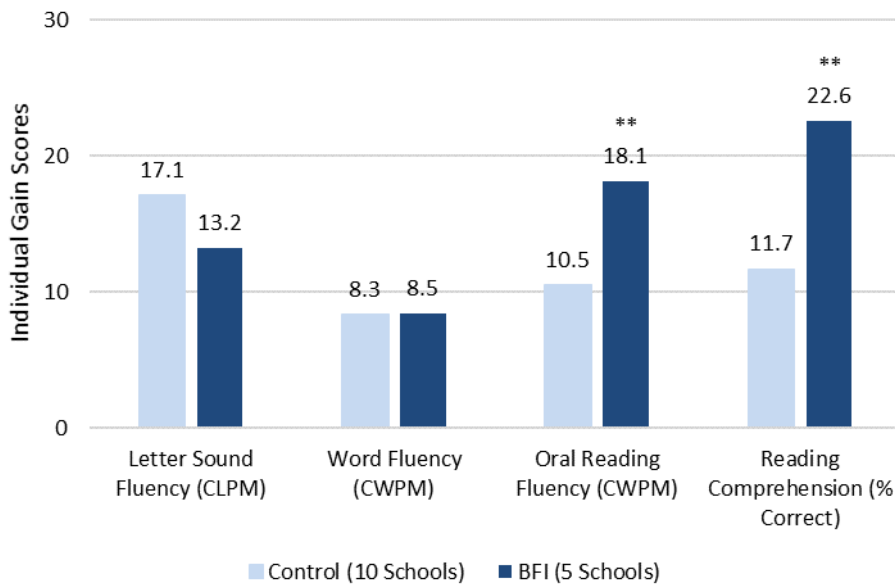


Figure 3. Individual Gain Scores by EGRA Component and Treatment Group, 2015.

BFI had positive and statistically significant effects on mother tongue reading fluency and comprehension. There were no significant differences between groups for letter sound fluency or familiar word reading. Stars signify statistically significant differences at the $p < 0.01$ level.

The next pair of figures illustrate the repeated measures scores on the ORF and reading comprehension gain scores, respectively.

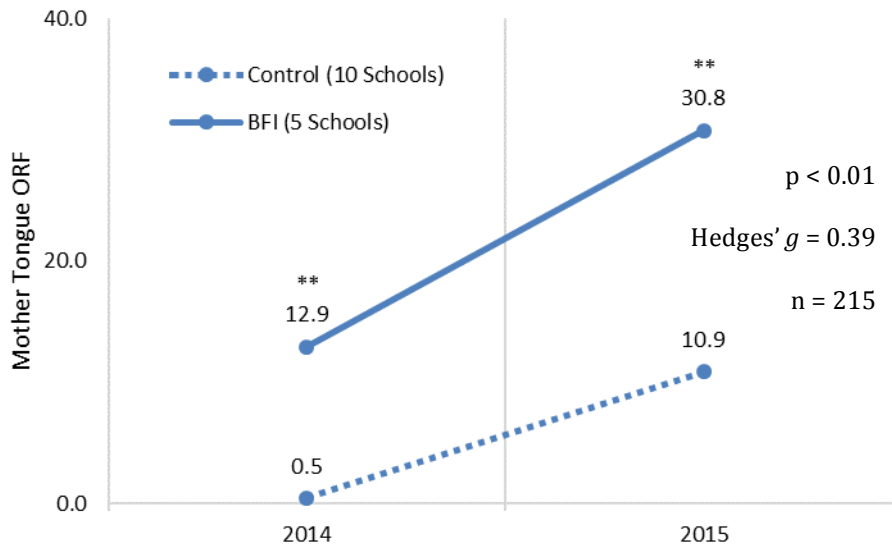


Figure 4. Repeated Measures Mother Tongue ORF Scores by Treatment Group.

After one year of the intervention (2015), the BFI curriculum significantly increased early literacy gains in treatment schools, compared to control schools. In treatment schools, the mean ORF gain score was 18.1 (SD 20.4). In control schools, the mean ORF gain score was 10.3 (SD 18.7).

	Control SD	BFI SD
ORF Pre	3.6	18.1
ORF Post	18.2	27.7

Table 18. ORF Pre and Post Assessment Standard Deviations by Treatment Group.

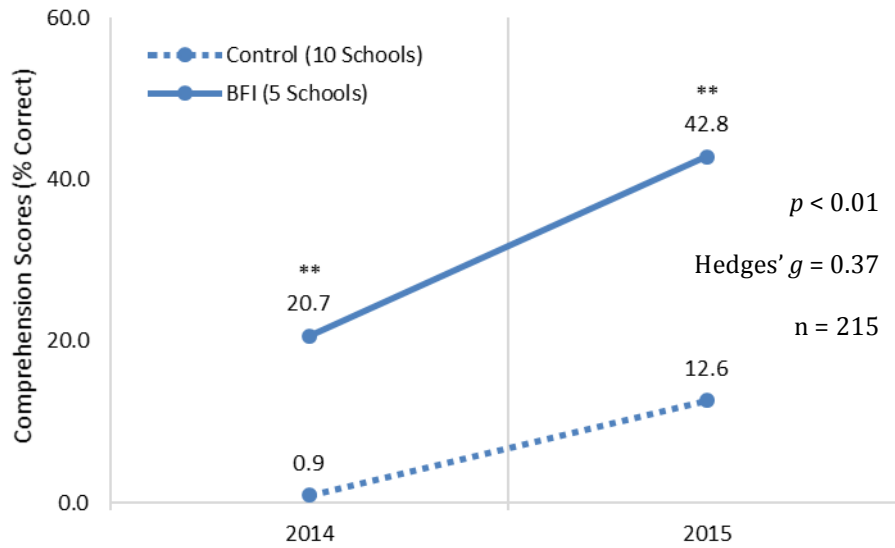


Figure 5. Mother Tongue Comprehension Scores by Group. After one year of the intervention (2015), the BFI curriculum significantly increased reading comprehension gains in treatment schools, compared to control schools. In treatment schools, the mean difference in comprehension scores was 22.6 (SD 31.3). In control schools, the mean difference in comprehension scores was 11.5 (SD 27.4).

	Control SD	BFI SD
Comprehension Pre	7.4	31.0
Comprehension Post	26.1	38.0

Table 19. Comprehension Pre and Post Assessment Standard Deviations by Treatment Group.

In addition to the treatment effect on literacy outcomes, females were also associated with significantly greater ORF gain scores than their male counterparts. However, grade level and school quintile were not associated with significant ORF gain scores within this sample.

To further explore the relationship across languages, the following figure presents the reading outcomes broken out by distinct mother tongue language for grade 2 learners. Results show that the effects varied across languages substantially with the Tshivenda language group outscoring the other language groups on all EGRA components. The Sepedi language group showed the lowest gain scores on each measure except for reading comprehension. However, it should be noted that the Sepedi language group represented the smallest sample across languages. This reduced sample size is the result of dropping the other Sepedi treatment school that was non-compliant with the implementation plan as noted in Chapter 4.

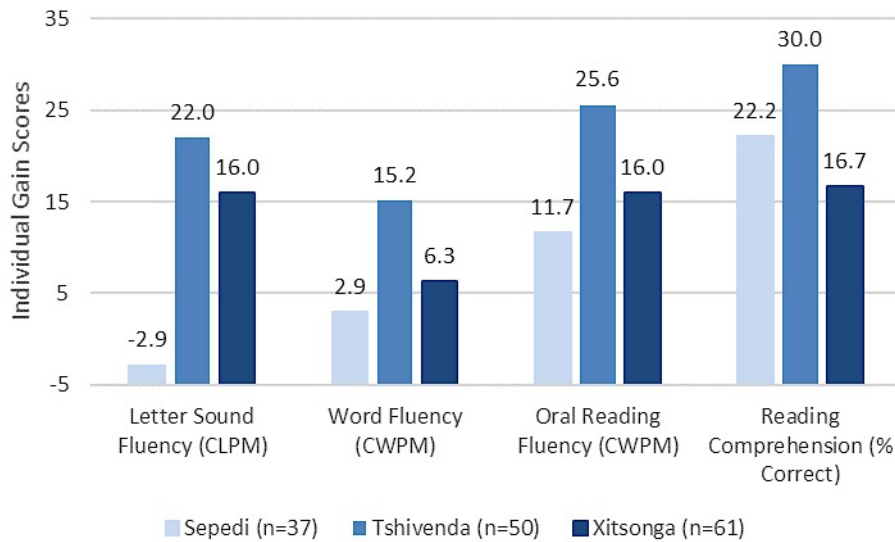


Figure 6. Individual Gain Scores by EGRA Component and Mother Tongue, Treatment Group, 2015.

Tshivenda learners outscored the other language groups on all measures. The Sepedi language group recorded the lowest gain scores on each component except for reading comprehension.

A fixed effects (FE) model on the individual gain scores was applied to further analyze the BFI impact. One way to describe the individual FE model is that it estimates separate regressions within each individual and then averages those coefficients across children (Allison, 2009). Individual FE models are appealing for longitudinal data in that they produce standard errors that adjust for dependence in repeated measurements. FE models also offer the function of automatically accounting for all unobserved, time-invariant characteristics at the individual and cluster levels (namely unchanging personality characteristics and parental background characteristics as well as unchanging school effects) (Allison, 2009).

Within the FE model with individual difference scores, BFI impact on oral reading fluency remained positive and significant ($t = 2.7$; $p < 0.01$). The intra-class correlation for the pre/post individual FE model is 0.65. Like the DID model, the BFI effect can be associated with a difference in gain scores by almost eight correct words per minute over the control group. Grade progression and the covariate for time were not significant within the FE model. As indicated, girls showed significant ORF gains over boys within the DID model. However, a test for an interaction of sex with the treatment effect within the FE model was associated with no difference in the impact of the BFI intervention by sex ($t = -1.63$; $p = 0.1$).

While the treatment effect was positive and significant at endline assessment, longitudinal analysis showed that the treatment effect was not sustained one-year after

the treatment ended (Model III below). Teacher interviews at one-year follow up revealed that the intervention had not been continued into the 2016 school year. The table below presents the coefficient estimates across each of the models referenced.

Variable	Model I Delta ORF (Clustered SE)	Model II Pre/Post FE Model (Robust SE)	Model III Longitudinal FE (Robust SE)
Treatment	6.9* (2.8)	7.8** (2.9)	4.3 (3.3)
Female	5.4* (2.7)	Omitted	Omitted
Grade	11.5 (7.5)	-1.9 (10.9)	6.6 (6.2)
School Quintile	-1.5 (1.6)	Omitted	Omitted
Time			
1	Omitted	12.2 (11.3)	6.4 (6.6)
2	NA	NA	16.3 (12.3)
Constant	-12.4 (16.0)	11.1 (11.9)	1.9 (6.8)
Obs	214	430	593
Groups	214	215	215
F Statistic (Model)	3.6**	45.9***	73.2***
R-Squared	0.07	0.64	0.70

*p < 0.05; **p < 0.01; ***p < 0.001

Table 20. Model Comparison of BFI Impact on ORF Outcomes.

Similar to the oral reading fluency outcome measure, DID estimation indicated that the BFI intervention was also associated with a significant and positive effect on reading comprehension. This result was supported within the pre/post individual fixed effect model ($t = 2.42$; $p < 0.05$). The intra-class correlation for reading comprehension within the FE model was 0.66. This difference is associated with double the comprehension score over the placebo control group within this sample. None of the other covariates were associated with statistically significant coefficients within the first two models.

Again, longitudinal analysis revealed that the treatment effect was not sustained one year after the intervention. The coefficient on time (wave of assessment) became the most significant predictor on improved comprehension scores when all three waves were included in the model. The coefficient on the time variable was associated with a 26% increase in comprehension measure from baseline to endline with an expected gain of 63% when comparing wave 3 to baseline outcomes. The table below presents the coefficient estimates across each of the models referenced.

Variable	Model I Delta Comp. (Clustered SE)	Model II Pre/Post FE (Robust SE)	Model III Longitudinal FE (Robust SE)
Treatment	11.3** (4.2)	10.6* (4.4)	1.4 (4.2)
Female	6.3 (4.1)	Omitted	Omitted
Grade	2.2 (11.4)	-16.8 (18.9)	-8.9 (9.1)
School Quintile	2.9 (2.4)	Omitted	Omitted
Time			
1	Omitted	28.0 (19.7)	26.8** (9.9)
2	NA	NA	63.2*** (18.0)
Constant	-2.6 (24.2)	32.9 (20.6)	25.3 (10.1)
Obs	214	430	572
Groups	214	215	215
F Statistic (Model)	2.7*	30.1***	78.0***
R-Squared	0.04	0.61	0.64

*p < 0.05; **p < 0.01; ***p < 0.001

Table 21. Model Comparison of BFI Impact on Reading Comprehension Outcomes.

In addition to the inferential models presented above, additional composite data was calculated to describe the context of reading outcomes within this sample.

Composite scores were comprised of mean scores across three EGRA subtasks including letter recognition, familiar word reading, and reading accuracy. The following three

tables present results by gender, urbanicity, and quintile rank, respectively. The first table shows that girls performed better than boys overall in both treatment conditions. Also, girls produced greater gains over time than their male counterparts. Mean composite scores for boys in the treatment schools increased by 68.2%, from an average of 0.22 to 0.37 through wave 2 (2015). One year removed from the program, this increase was reduced to 29.7%, from an average of 0.37 to 0.48 through wave 3 (2016). Meanwhile, composite scores for girls increased by 78.6% and 26%, respectively.

Gender	2014		2015		2016	
	Control	BFI	Control	BFI	Control	BFI
Boys	0.04	0.22	0.17	0.37	0.37	0.48
Girls	0.03	0.28	0.22	0.50	0.53	0.63

Table 22. Mean Composite Scores by Treatment and Gender, 2014 – 2016.

The next table presents mean composite scores by urbanicity. Initially, treatment schools in rural settings outperformed treatment schools in urban settings by the end of wave 2. The mean increase for rural schools was 80.2% versus 59.3% for urban sites from 2014 to 2015. However, by wave 3 this effect reversed whereby urban schools outperformed rural schools from 2015 to 2016 by a margin of 28.5%. Although, it should be noted that overall mean composite scores were consistently higher among rural learners throughout the study period and regardless of treatment assignment.

Urbanicity	2014		2015		2016	
	Control	BFI	Control	BFI	Control	BFI
Rural	0.06	0.29	0.20	0.53	0.50	0.62
Urban	0.03	0.18	0.20	0.29	0.45	0.44

Table 23. Mean Composite Scores by Treatment and Urbanicity, 2014 – 2015.

As noted earlier, the BFI program was developed for and implemented among the lowest performing schools in the province. The following table shows the breakdown of mean composite scores by school quintile rank. Interestingly, schools in the two lowest quintiles showed mean scores higher than those of the other quintile. However, the increases were not substantially different overall across quintile classifications. This outcome is consistent with the nonsignificant results for this predictor variable across model specification as discussed above. Taken together, the BFI intervention was effective in directly improving reading outcomes in lower performing schools, regardless of quintile classification.

Quintile	2014		2015		2016	
	Control	BFI	Control	BFI	Control	BFI
Lowest	0.09	0.31	0.11	0.47	0.41	0.63
Lower	0.03	0.28	0.20	0.57	0.46	0.61
Low	0.03	0.18	0.22	0.29	0.47	0.44

Table 24. Mean Composite Scores by Treatment and School Quintile Rank, 2014 – 2016.

The following section presents the correlational findings related to the second research question on literacy transfer.

R2 Findings: Literacy Transfer

Research Question 2: Is there a distinct correlation for literacy outcomes from mother tongue to a first additional language?

The second research question investigated a structural break in the data by which transfer of mother tongue literacy skills was best predictive of reading outcomes in a first additional language. For the purpose of this study, a structural break is defined as a significant change in the slope of the fitted regression line.

The following table presents the cross-sectional Pearson correlations for bilingual decoding over time. Overall, the bilingual decoding relationship differed between 0.78 and 0.90 from 2014 to 2016 and appeared to increase in magnitude with the sample size.

	2014 (n)	2015 (n)	2016 (n)
Pearson's r	0.78	0.80	0.90
Coefficient	(41)	(159)	(217)

Table 25. Pairwise Correlations of Bilingual Decoding, by Year.

Examining the relationship by language group revealed correlations between 0.83 and 0.88 in magnitude as referenced in the table below.

	Sepedi (n)	Tshivenda (n)	Xitsonga (n)
Pearson's r	0.88	0.83	0.87
Correlation	(85)	(229)	(103)

Table 26. Pairwise Correlations of Bilingual Decoding, by Mother Tongue Language.

The figure that follows presents the scatterplot of the combined data over all three cross-sections. The illustration depicts a fanning out of the data at the top end of the achievement spectrum.

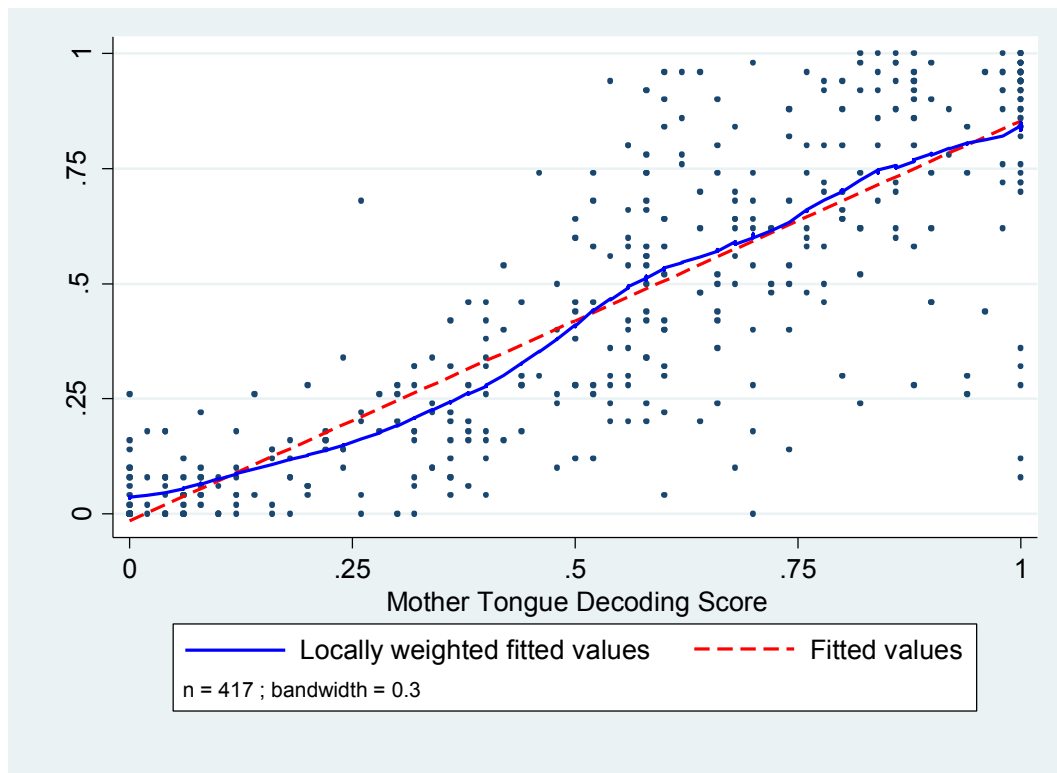


Figure 7. Scatterplot of Mother Tongue and English Decoding Scores with Fitted Values.

Locally weighted fitted values depict a structural break in literacy transfer at approximately .25 proficiency in mother tongue decoding and return to an original fit at about .60 proficiency in mother tongue decoding.

Visual inspection of the scatterplot illustrates a structural break in literacy transfer at approximately .25 proficiency in mother tongue decoding. This potential cutoff value represents a decoding fluency of 12.5 correct words per minute. At approximately .60 proficiency in mother tongue decoding, the locally weighted slope begins to return to an original fit. This second value represents a decoding fluency of 30 correct words per minute.

To further analyze this threshold hypothesis, the data was estimated using multivariate regression with standard errors clustered by school ID. In addition to the primary predictor variable of mother tongue decoding proficiency, covariates for FEMALE, GRADE, and URBAN were included as controls. The table below presents the respective coefficient estimates.

English Decoding Score	Below 0.26 (Clustered SE)	Between Cutoffs (Clustered SE)	Above 0.59 (Clustered SE)
Mother Tongue Decoding Score	0.46*** (0.10)	1.29*** (0.20)	0.76*** (0.09)
Female	0.00 (0.01)	0.04 (0.03)	0.00 (0.02)
Grade 3	0.04** (0.01)	0.09* (0.03)	0.17* (0.06)
Grade 4	0.15*** (0.01)	-0.02 (0.04)	0.21* (0.09)
Urban	0.01 (0.01)	0.09† (0.04)	0.08† (0.04)
Constant	0.01 (0.01)	-0.32** (0.08)	-0.07 (0.06)
n	107	117	193
R-Squared	0.32	0.46	0.33
Root MSE	0.06	0.17	0.20

† approaches significance; *p < 0.05; **p < 0.01; ***p < 0.001

Table 27. Multivariate Regression of Decoding Transfer at Approximated Cutoff Values.

The output above indicates that the relationship of decoding skills transfer is almost three times greater between the cutoff points (1.29) than below (0.46). At the upper value, the coefficient remained larger than the lower cutoff value but to a lesser magnitude. Pairwise comparison of English decoding scores with mother tongue decoding revealed positive and significant correlations at each value. However, the

magnitude of the correlation was 28% to 36% larger between the cutoff points ($r_{\text{between}} = 0.60$) as compared to outside the approximated values ($r_{\text{lower}} = 0.47$; $r_{\text{upper}} = 0.44$).

The first part of this finding supports the threshold hypothesis in that after a certain level of proficiency in mother tongue decoding, transfer of skills to English were better supported. However, this relationship appears to have diminished as mother tongue proficiency increased beyond the upper value. Notwithstanding this result, the coefficient estimates on mother tongue decoding proficiency indicate that the relationship was still associated with better English language decoding proficiency at the upper value ($\beta = 0.76$; $p < 0.001$) than at the lower value ($\beta = 0.46$; $p < 0.001$).

As expected, grade level was a significant predictor of improved literacy transfer at each level of progression when compared to grade 2 proficiency. Another relationship of note is the coefficient for URBAN beyond the lower cutoff value. While this coefficient estimate only approached significance at the 0.05 level, it is possible that learners residing in urban settings may have benefited more from transfer of skills than their rural peers once they reached a minimum proficiency level.

An analysis of a structural break was conducted to formally test the differences in the coefficients of decoding skills transfer between each group. The procedure consisted of estimating a fully interacted model for the cutoff values with each of the predictor variables. The set of coefficients for the groups were then tested against the hypothesis that there were no group differences in the relationship between the predictor variables overall.

Test results were associated with a significant structural break at the approximated value of 25% proficiency in mother tongue decoding ($F(2,16) = 7.65$; $p < 0.01$). Therefore, these results show that transfer of decoding skills significantly improves once learners reach a certain level of proficiency in their mother tongue language. However, this “bonus” in literacy transfer appears to disappear once learners achieve a higher level of mother tongue decoding proficiency, within this sample. Results are reported in the table below.

English Decoding Score	Coefficient† (Robust SE)
Overall Mother Tongue Decoding Score	0.46*** (0.10)
Decoding Score Between Cutoffs	-0.33** (0.09)
Decoding Score Upper Cutoff	-0.08 (0.06)
Interaction Between Cutoffs	0.83** (0.27)
Interaction Upper Cutoff	0.31 (0.17)
Constant	0.01 (0.01)
Observations	417
R-Squared	0.77
Root MSE	0.17

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

† Reported coefficients include controls for female, grade, and urbanicity with corresponding interactions by group.

Table 28. Test for Structural Break in Relationship of Decoding Skills Transfer.

To further examine the distribution among the learners in the correlational sample, the breakdown of cutoff values is illustrated below. The figure shows that by mid-year in their respective grades, one third of Grade 2 learners had not demonstrated

sufficient mother tongue decoding skills to make substantial improvements in their English decoding. This number only reduced to about one in four learners by mid-point of Grade 3.

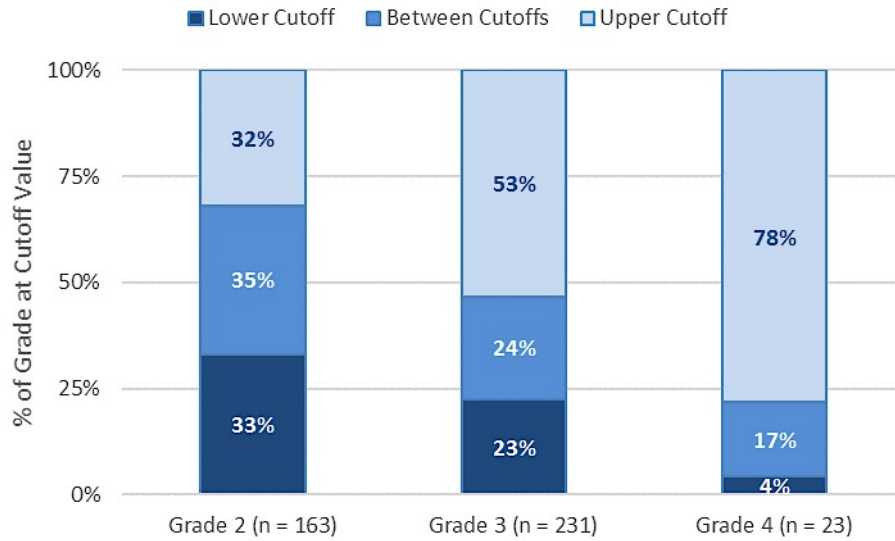


Figure 8. Distribution of Cutoff Values in Literacy Transfer by Grade. By mid-year in their respective grades, a third of Grade 2 learners had not demonstrated the necessary mother tongue decoding skills to make substantial improvements in English decoding. This number reduced to one out of four learners by the mid-point of Grade 3.

6. Discussion

This study departs from previous research in two important ways. First, research on ICT literacy interventions have largely focused on English language content or unguided software (Wagner, 2014). This study incorporates student-centered material through a structured and remediated approach in three South African mother tongue languages and English. Secondly, previous research relies heavily on cross-sectional, repeated measures design to determine program effectiveness. Sampling variability within this method could lead to an underestimation of the standard errors and over estimation of program impact (Allison, 2009). This study incorporates panel analysis by tracking the same learners over a three-year period and collecting literacy data in both mother tongue and English for each learner.

This research was conducted in the northern province of Limpopo, South Africa among learners in grades 1 through 4. An experimental design was used to investigate outcomes along two lines of inquiry: R1) estimate the impact of a school-based literacy program on early reading proficiency in both mother tongue and English; and R2) investigate transfer of literacy skills from mother tongue to English.

Data was collected over a three-year period from 2014 to 2015 with a one year follow up in 2016. The primary data for analysis along both lines of inquiry was collected through individual surveys consisting of four components: letter sound, familiar word reading, short passage reading, and reading comprehension. During year one, only mother tongue instruments were administered due to limited English language

proficiency among learners. In waves two and three, learners were assessed in both languages.

R1: Does BFI improve early reading outcomes in rural South Africa?

The first research question analyzed whether well-prepared digital materials can improve early reading outcomes in rural South Africa. The outcome variable of interest was change in oral reading fluency with BFI group assignment as the main predictor variable. See Chapter 4 for further detail about the methodology and instrument validation.

Findings supported the hypothesis that BFI would improve early reading outcomes, with reservations. 2015 Endline results are associated with positive and significant effects on two primary reading outcomes: mother tongue reading fluency and reading comprehension. Individual gain scores represent an effect size of 0.39 and 0.37, respectively. Each of these effect sizes can be associated with double the gains in literacy achievement over the counterfactual group. Findings of this magnitude are within the same range of other non-technology enabled research on mother tongue early reading interventions in South Africa (Piper, 2009) and with non-student-centered technology use in Kenya (Piper, 2014; Piper et al., 2016).

These findings were further substantiated when applied to a fixed effects regression model. In addition to improving efficiency in estimating change over time, fixed effects methods offer the added benefit of controlling for all unchanging characteristics of the individuals, whether observed or unobserved (Allison, 2009).

Within a fixed effects model, variance associated with school clustering and time-invariant background characteristics are accounted for when estimating the treatment effect. For this sample, findings show that the BFI program is effective in improving mother tongue early reading outcomes.

Analysis of early reading composite scores revealed that girls outperformed boys in both treatment conditions and produced greater gains over time. Urbanicity and quintile classification were also introduced for assessing the effectiveness of the BFI intervention. Within this sample, treatment schools in rural settings outperformed their urban counterparts overall. However, quintile classification did not produce discernable differences related to program effectiveness.

The findings from this study confirm the conclusions outlined in both the Design Solutions Framework (Wagner et al., 2014) and the Results Based Framework (Arias Ortiz & Cristia, 2014). ICT software best supports learning when incorporated through a guided-use platform that is designed with the end-user in mind. While control schools included in this study did not use the BFI program, learners were given access to digital content through similar, school-based computer labs. The main difference between the two groups was the intentional structuring of the BFI curriculum through language-specific and grade-appropriate content.

R2: Is there a distinguishable correlation for predicting transfer of literacy skills to a first additional language?

This second line of inquiry investigated correlational literacy outcomes among learners in both mother tongue and English over two waves data collection (2015 & 2016). Within this second component of the research, the outcome variable of interest was English language decoding (correct words per minute) with mother tongue decoding as the primary predictor variable.

Findings provide evidence in support of the Developmental Interdependence Theory (Cummins, 1980). Transfer of skills to a first additional language was positive and significant along varying levels of mother tongue proficiency. Further, locally weighted regression analysis of decoding skills was associated with a clear structural break at a lower limit of approximately 0.25 proficiency in mother tongue decoding or about 12.5 correct words per minute. Within this sample, learners recording a mother tongue decoding proficiency beyond this lower value demonstrated a “bonus” in transfer of skills to English equivalent to almost three times the proficiency in transfer of skills below this value. However, the literacy transfer “bonus” effect appears to be no different than the initial correlation once learners reach an upper proficiency value of approximately .60, or 30 correct words per minute.

Formal hypothesis testing of this structural break at each cutoff value was significant and explained 75% of the variation in English decoding scores within this sample (see Chapter 5 for further detail). This conclusion implies that learners who do

not demonstrate decoding proficiency in the mother tongue beyond the lower proficiency level may struggle to develop similar skills in a first additional language.

The current policy in South Africa mandates English language instruction to be introduced across all grade four classrooms. Outside of the present study, no empirical justification of this policy is available. Within this sample, one third of Grade 2 learners do not have mother tongue decoding skills beyond the indicated cutoff point. By mid-year of Grade 3, this proportion is only reduced to one in four learners. This implies that more than a quarter of learners may be advancing into instruction in a first additional language without establishing sufficient foundational reading skills in their mother tongue.

7. Conclusions

Even with impressive gains in universal access to primary education, reading skills remain low in rural South Africa. Mother-tongue instruction remains a serious challenge for ensuring quality learning environments in multilingual settings throughout the region (Moloi & Chetty 2010). Limited teacher capacity compounds deficiencies among struggling learners (DBE, 2008). For many students, simple, grade appropriate learning material developed in their home language is unavailable or unclear.

Expanding access to technology at much lower costs has prompted innovative approaches to learning and positioned ICTs as a major enabling tool for achieving the universal education agenda. However little evidence exists supporting the impact of ICT interventions in developing country contexts. Through a quasi-experimental design, this research investigated the impact of a user-centered multimedia platform for improving early reading outcomes in linguistically diverse and under-resourced settings. This study also analyzed the relationship in linguistic interdependence for successfully supporting the transfer of reading skills to a first additional language.

R1: BFI Impact. Review of Findings, Limitations and Future Research

Research on the integration of theoretical frameworks for deploying ICT within developing country contexts is generally lacking (Hinostroza et al., 2014). The conceptualization of the BFI impact component of the study was modeled after the Design Solutions Framework for ICT integration in low-income countries (Wagner et al., 2014). The Simple View of Reading (SVR) framework (Gough & Tunmer, 1986) and the

National Reading Panel framework (NICH, 2000) provided the theoretical foundation for the curricular design of the BFI software as well as the primary data collection instrument.

The findings supported the hypothesis that reading performance can be enhanced through well-developed and contextualized digital material in under resourced settings with diverse learner needs. Learners that were introduced to the guided BFI software produced greater gains in both oral reading fluency and reading comprehension outcomes. While sustainability of the findings was limited after the conclusion of the study, the preliminary results offer important insight for improving future efforts within this research domain.

A serious vulnerability of the analysis applied in Chapter 4 is the assumption that the initial difference will remain stable over time and in the absence of an intervention effect. If this assumption is upheld, the estimate of the effect is then the over-time change in slope between the two groups. However, another plausible explanation of the observed group differences in slopes over time is what has been referred to as the Matthew Effect (Stanovich, 1986). This fanning out effect describes a hypothesis whereby those with an initial advantage always gain more than those at disadvantage, all other conditions held constant.

However, the one-year follow-up data refutes the fanning out hypothesis. Along this Matthew Effect assumption, the treatment schools should have continued to advance in their achievement trajectory, but the data reported in Chapter 5 does not

support this outcome. Therefore, it is plausible that the BFI program was responsible for the observed differences over time, and not the fact that the treatment schools started off at higher level of reading achievement.

Low fidelity to implementation is more likely a cause of this reduction in the treatment effect over time. Site-based observations and interviews with school administrators revealed that only two of the treatment schools continued the BFI implementation into the third year by the time the additional round of data collection had begun. Overall, malfunctioning hardware and delayed implementation into the third term of the school year were cited as primary reasons for discontinued use. Site visits revealed that the BFI program had been installed in many of the control schools although there was no clear indication of program use. Both instruction and motivation appear to be key factors influencing the results. Nevertheless, the initial results are promising as the study did encounter problems related to fidelity to implementation across schools and problems related to the evaluation design due to limited resources.

Site visits prior to implementation revealed that while schools may have functioning computers on site, the labs were not always intended for student use. Therefore, self-report of minimum technical requirements for ICT deployment should be accompanied by more formal accountability measures to ensure alignment with the program implementation plan. Given the expansion in access to and support of student-centered technology interventions in developing countries, future research should more intentionally investigate fidelity to implementation with ICT.

One component that could have strengthened these findings is a more precise estimation of time on task. This study developed a paper-based metric for capturing time on task data at both the classroom and individual level. However, monitoring reports revealed only minimal adoption among the control schools. To avoid the additional burden on teachers and computer lab technicians, future studies that incorporate ICT should build in an automated data capture mechanism for improved monitoring.

Another aspect to consider when deploying educational innovation interventions is the total cost of implementation. Hardware is only one component of ICT programming. Initial training or readily available technical support for troubleshooting complications with the program are often underbudgeted or unaccounted for within ICT interventions. Very few evaluations have incorporated a cost component when assessing ICT use in schools, including the present study. New variations of ICT programming include a Bring Your Own Device (BYOD) approach that reduces upfront hardware costs. More research comparing variations of ICT inputs and the respective costs per unit of learning will be critical for informing the future of educational innovation in under resourced settings.

Continuous training on the application of the software within the classroom literacy curriculum is important for improving sustainability and buy-in from teachers. This study made provisions for initial training and orientation to the national reading strategy, but sustained efforts would have improved teacher capacity and

implementation fidelity.

A complication of the evaluation was the ambiguity of the sample selection. Initially, a randomized controlled trial was intended with stratified random sampling at the school level. However, the randomization revealed heterogeneity between treatment groups as observed in the baseline hypothesis tests converting the study into a quasi-experimental design. While the longitudinal analysis attempted to correct for this inherent bias, a better controlled random sampling of schools is recommended for future research.

Notwithstanding these limitations, the findings demonstrated useful evidence for considering future expansion within Limpopo and other South African provinces. However, central to any expansion activity should be a discussion about improving and extending the existing BFI materials.

Several recommendations follow:

1. Future efforts should include a more extensive training and formative evaluation plan to ensure consistent oversight and fidelity to implementation.
2. Improved data collection as well as expanded sample sizes will be crucial for ascertaining cross-age and cross-language impacts.
3. Tablet devices are a natural platform to extend research with the BFI software and were only just recently being distributed to former control schools at the conclusion of this intervention. More research is needed to

determine whether tablet devices produce different gains than traditional desktop computers.

4. For both modes of administration, additional research is also needed to determine the underlying reasons behind the observed gains and how the intervention affected learners along different levels of the achievement distribution.

R2: Literacy Transfer. Review of Findings, Limitations and Future Research

Mother tongue instruction is a real challenge for achieving the sustainable development goals for education. The literacy transfer line of inquiry within this study is informed by Cummins' Developmental Interdependence Hypothesis (1979) and his Language Threshold Theory (1980). See Chapter 2 for a detailed literature review.

Findings revealed that at a lower cutoff value of .25 decoding proficiency, learners demonstrated a substantial increase in the transfer of skills to English. However, at an upper cutoff level of approximately .60 mother tongue decoding proficiency, this effect was not significantly different than the correlation below the lower cutoff value. Within this sample, it appears that literacy transfer interacts differently at varying levels of proficiency. While the findings are associated with an initial boost in transfer of skills, the effect is diminished once learners reach an upper level of decoding proficiency.

This is an important finding within the context of South Africa. By mid-year of grade three, approximately one out of every four learners in this study had not yet

reached a basic level of proficiency in their mother tongue to benefit from transfer of reading skills to a first additional language. This implies that a substantial proportion of learners may be advancing into English dominant instruction without sufficient foundational reading skills to help them improve their learning.

The outcomes from this research have significant pedagogical implications for improving reading skills development within South Africa. Principally, it would produce better outcomes to introduce English decoding instruction only after learners have demonstrated sufficient proficiency in mother tongue decoding skills overall. Within this sample, over 20% of learners were performing below the indicated cutoff point by mid-year of grade four.

This recommendation may not be as straightforward to execute in all situations. Among schools in this study, classrooms reached up to 60 and 70 learners in some instances. Both practical and ethical concerns arise in limiting curricular advancement for strong readers to benefit struggling readers. When more than one teacher is available per grade, it may prove useful to split classrooms based on aptitude so that learners with lower reading skills receive the additional support they need. Alternatively, school pullout programs may provide the flexibility to work directly with specific learners without altering the curriculum for rest of the class.

This literacy transfer component of the present study could have been strengthened in various ways. Given the scope of resources and project timeframe, several decisions had to be made about the design of the data collection instrument.

The full version of the instrument includes eight components that assess several connected reading skills from orientation of print to oral vocabulary knowledge and listening comprehension. For this study, the instrument was reduced to the four activities that were deemed priority components for assessing early reading outcomes by local stakeholders. For an overview of program development and implementation see Chapter 3.

Future research should incorporate a broader battery of assessments that not only solicit knowledge with printed material, but also prompt for vocabulary knowledge through non-print material such as picture naming. This will offer a deeper understanding of literacy acquisition beyond recitation of familiar words.

As noted above, Grade 1 learners were not included in the correlational sample because of floor effects with English language proficiency. Most of the data upon which the findings were based include Grade 2 and Grade 3 learners with a much smaller sample of grade four learners ($n = 23$). Future research should extend the findings from this study to include a more robust sample of learners both within the foundation phase grades as well as upper primary levels. As noted in Chapter 1, 60% of South African learners are not competent in basic reading skills after six years of schooling (Moloi & Chetty, 2010). Therefore, a better understanding of literacy acquisition and transfer of skills throughout the full primary cycle is needed to help reduce disparities in reading outcomes for marginalized communities.

Finally, more experimentation with alternative models for supporting struggling

readers is imperative. This study applied a computer assisted learning (CAL) approach at the classroom level. Future research should build on this study by comparing the findings to a more targeted sampling approach with specific learner subgroups. Low-cost community-based approaches would provide important insight into the impact per unit of input of incorporating technology. This comparison would also have implications for scalability in under resourced settings.

Results from the literacy transfer component of this study help to explain how successful reading acquisition occurs among South African languages and English. This is one of the first studies to provide empirical evidence for establishing early reading benchmarks among foundation phase learners. Future research should continue to emphasize understanding the dynamics of learning for improving strategies toward successful literacy acquisition in linguistically diverse settings.

Final Thoughts

Overall, this research contributes to the literature on educational innovation in global and diverse contexts. The study led with the hypothesis that guided digital materials emphasizing student-centered instruction in their language of choice would produce greater gains in early reading achievement among foundation phase learners. An additional hypothesis stated that a distinct shift in the biliteracy slope would emerge for improving the successful transfer of early reading skills in mother tongue to a first additional language. Both hypotheses were confirmed through the present study. Together these findings help to verify strategies for advancing educational innovation in

linguistically diverse settings while informing bilingual education policy to best support struggling readers.

Despite the growing body of evidence about program effectiveness in low-income countries, there is still much to understand. This study represents one of the few cases where an evaluation of an intervention combined with a deeper understanding of how literacy acquisition occurs in cultural context. Future research should continue to incorporate strategies for understanding the mechanics of learning among students to enhance program design and support quality education environments. The impact of this research helps explain how even the most marginalized readers can make dramatic gains that will help them read, learn, and complete their schooling.

APPENDICIES

Appendix A: BFI Lesson Structure

- i. The story
- ii. Listening activity: key sentence
- iii. Construction activity: the key sentence (easier in first few lessons)
- iv. Listening activity: key word 1 in syllables
- v. Listening activity: key word 1 in sounds
- vi. Listening activity: key word 2 in syllables
- vii. Listening activity: key word 2 in sounds
- viii. Spelling game: key word 1
- ix. Spelling game: key word 2
- x. Phonemic awareness activity: Click on one of three words
- xi. Grammar activity 1: Identify the type of word, such as nouns, in a sentence
- xii. Grammar activity 2: Conjunctions or punctuation – drag-and-drop
- xiii. Reading activity: Comprehension test story
- xiv. Comprehension activity 1: Multiple choice
- xv. Comprehension activity 2: Multiple choice
- xvi. Comprehension activity 3: Multiple choice
- xvii. Typing activity (type three words)
- xviii. Workbook activity, such as drawing lines on maps, filling out a specific (non-generic) form, etc.

The number of each of the activities will be determined by the level of the lesson, as per the following table:

Activity	31-35	36-40	41-45	46-50	51-55	56-60
1 – Listening (key sentence)	1	1	1	1	1	1
2 – Construction	0	1	1	0	1	1
3 – Easy version Constr.	1	0	0	1	0	0
4-5 – Listening (Syllable)	2	2	2	2	2	2
6 – Listening (sounds)	2	2	2	2	2	2
7 – Typing	1	1	1	1	1	1
8 – Spelling game	2	1	1	1	1	1
9 – Reading text	1	1	1	1	1	1
10 – Comp. Activity	3	3	4	3	4	4
11-16 – Grammar	2	2	2	2	2	2
17 - Conjunction	0	0	1	1	2	2
18 - Punctuation	2	2	1	2	1	1
19 - Comma	0	0	1	0	1	1
20-21 Phonemic Awareness	3	3	3	4	4	4

Appendix B: Procedure for District Selection and Treatment Assignment

The Limpopo Province was chosen for this research based on the following justifications:

- Low provincial performance as demonstrated by ANA results and international testing
- Strong relationships established between the Molteno Institute (implementing partner organization) and the Limpopo Department of Basic Education
- Adequate ICT access among schools in province

Treatment School Selection

The following list of critical success factors was used to identify specific schools to target for the BFI study:

1. Schools under the jurisdiction of the Limpopo Department of Education (LDoE).
2. Schools in quintile 1-3 (no-fee schools).
3. Schools with at least 10 working computers for learner use.¹
4. Schools with computers that ran on the Windows OS platform (based on technical specifications from the software developer).
5. Schools willing to work with the BFI intervention (as demonstrated through signed MOUs from each of the intervention schools involved in the study).

This criterion sampling approach was submitted to the LDoE, which resulted in a working list of 50 schools. Site visits later confirmed that five schools had computer labs which only ran Linux and an additional eleven were found to either have no computers, broken computers, or computers which were too old to upload or operate the BFI program.

A second list of schools was then received from the LDoE. Only after several rounds of additional investigation was a suitable number of schools confirmed. The majority of non-viable schools were concentrated in the Venda speaking areas of Limpopo. This resulted in a sample which was unevenly distributed by language. See total distribution by language in Chapter 4.

¹ This was ultimately a compromise from the proposal, which indicated that schools must have no more than a 2:1 learner: computer ratio. Upon implementation, very few schools actually met this criterion. Classrooms had far more learners than accepted by the National Norms and Standards in each class (or classes were “divided” but in the same room with the same teacher) and many computers were not functioning which were reported to be functional.

Control School Selection

Control schools were determined based on location, quintile and number of learners to be comparable to the “average” intervention school. Two control schools were originally identified per language. However, these control schools declined to participate in the study and part of the original intervention group was reassigned to the control group.² Schools were reassigned based on their noncompliance in implementing the BFI program during the pilot testing period. Ultimately, ten schools were reassigned to the control group at baseline prior to the rollout phase.

Evaluation School Selection

In the original research design all 50 BFI schools were included in the intervention group. However, after midline review it was found that fidelity to implementation was very low, and that the funds available did not allow for a project of that scope to be monitored with any efficacy. Therefore, two schools per language (a total of six schools) were selected which observing personnel felt were most likely to implement the program, based on the following observations recorded from site visits:

- Current use of the program
- Number of computers available
- Condition of the computer lab
- Staff feedback

² Factors for declining to participate in the study included the length of school time required to test learners using the EGRA, perceived risk and lack of perceived benefit.

Appendix C: List of Evaluation Schools Included in the Research

Control Schools	Language
Maribe	Sepedi
Matshumu	Sepedi
Ntji-Mothapo	Sepedi
Phishoana	Sepedi
Maniini	Tshivenda
Muratho	Tshivenda
Nanga	Tshivenda
Dududu	Xitsonga
Ninakhulu	Xitsonga
Ritavi	Xitsonga

BFI Treatment Schools	Language
Mponegele	Sepedi
Folovhodwe	Tshivenda
Mauluma	Tshivenda
Bombeleni	Xitsonga
Samson Shiviti	Xitsonga

Appendix D: Adapted Early Grade Reading Assessment, English

General Instructions

It is important to establish a relaxed attitude through some simple initial conversation of interest to the child. The child should perceive the assessment more as a game than a formal assessment. After you have finished, thank the child and give him/her a pencil as a token of appreciation.

Verbal Consent

Read the text in the box to the child:

My name is _____. I'm working with the Molteno Institute for Language and Literacy.

- **We are trying to understand how children learn to read. You were picked by chance, like in a raffle or lottery.**
- **We would like your help in this. But you do not have to take part if you don't want to.**
- **I'm going to ask you to sound out letters, and read words and a short story out loud, and then may ask you a few questions about the story you read.**
- **Using this stopwatch, I will see how long it takes you to do these things.**
- **This is NOT a test and it will not affect your grade at school.**
- **I will NOT write down your name so no one will know that these are your answers.**
- **Once again, you do not have to participate if you do not wish to. Also, once we begin, if you'd rather not answer a question, that's all right.**
- **Can we get started?**

Tick box if verbal consent is obtained:

YES

(If verbal consent is not obtained, thank the child and move on to the next child)

A. Date of Assessment:	
B. Assessor's Name:	
C. School Name:	

D. Student's Gender	<input type="radio"/> girl	<input type="radio"/> boy
E. Birth Information:	Month: Year: Age:	
F. Pre-School Attendance	<input type="radio"/> yes	<input type="radio"/> no

1. Letter Sounds (LS)

Show the learner the chart of letters (Chart 1).

Here is a page full of letters. I would like you to sound as many letters as you can. You will start here and move across the page. (Point to the leftmost letter on the top row of the exercise, moving from left to right.) **When I say, 'Begin', you will sound the letters as best you can. Point to each letter as you sound it. If you don't know the sound of a letter, just skip it.**

Let's practice first. (Point to the first example letter, moving from left to right, to practice the instructions given above.)

Ok, now we're ready to begin. Put your finger on the first letter. Ready? Begin.



- Start the timer when the child starts.
- Strike a line through a letter that the learner sounds incorrectly or cannot sound at all. For example: ~~b~~
- If the learner stops for more than 3 seconds, tell the learner to go on and strike a line through the letter. For example: ~~b~~
- If the learner corrects himself/herself, accept it as correct. (If a strike has already been made on the letter, circle it to mark it correct.)
- If the entire first line has strike-through lines across all the letters, stop the assessment, place a bracket (]) after the last letter on the first line and make a tick mark (✓) at the bottom of the exercise (in the box provided) to record that the exercise was discontinued.
- After one (1) minute, say "**Stop**". Place a bracket (]) after the last letter that the learner has attempted to sound.
- Count and record the number of letters that the learner sounded correctly.
- If the learner sounds all the letters in less than one (1) minute, record the time remaining on the stopwatch at the bottom of the exercise.

Example 1

B	L	h	g	S	y	R	W	L	N	/10
l	K	T	D	K	T	p	d	r	w	/10
h	W	r	m	U	r	j	G	P	u	/10
g	R	B	J	l	f	l	R	s	r	/10
S	N	A	B	p	Y	F	a	a	E	/10
y	S	P	P	M	b	O	t	n	P	/10
R	A	e	e	f	F	h	u	A	t	/10
W	G	H	b	S	l	g	m	i	L	/10
L	L	o	o	P	N	E	Y	p	p	/10
N	K	a	D	d	y	b	j	R	b	/10
B	M	W	p	B	l	h	g	S	y	/10

Number of letters read by the learner in ONE MINUTE	/110
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2. Word Reading (WR)

Show the learner the chart of words (Chart 2).

Here is a page full of words. I would like you to read aloud as many words as you can. Do not spell the words but read them. You will start here and move across the page. (Point to the leftmost word on the top row of the exercise, moving from left to right.) **When I say, 'Begin', you will read the words as best you can. Point to each word as you read it. If you don't know a word, skip it.**

Let's practice first. (Point to the first example word to practice the instructions given above.) **This word is cat.**

Now you try: [point to the next word: "dog" and say] **please read this word**

[If correct]: **"Very good: dog"**

[If incorrect]: **This word is "dog."**

Ok, now we're ready to begin. Put your finger on the first word. Ready? Begin.



- Start the timer when the child starts.
- Strike a line through a word that the learner reads incorrectly or cannot read at all. For example: ~~cat~~
- If the learner stops for more than three (3) seconds, tell the learner to go on and strike a line through the word. For example: ~~cat~~
- If the learner corrects himself/herself, accept it as correct. (If a strike has already been made on the word, circle it to mark it correct.)
- If the entire first line has strike-through lines across all the words, stop the assessment, place a bracket (]) after the last word on the first line and make a tick mark (✓) at the bottom of the exercise (in the box provided) to record that the exercise was discontinued.
- After one (1) minute, say: **"Stop"**. Place a bracket (]) after the last word that the learner has read correctly.
- Count and record the number of words that the learner read correctly.
- If the learner reads all the words in less than one (1) minute, record the time remaining on the stopwatch at the bottom of the exercise (in the box provided).

Word Reading, CHART 2

Examples: cat dog

I	a	you	he	his	/5
hot	can	buy	pat	we	/5
man	not	van	lip	tap	/5
dog	read	win	but	rat	/5
pot	eat	jam	fat	tin	/5
work	are	ball	get	run	/5
hand	fill	men	net	use	/5
wet	bat	need	kick	have	/5
play	want	give	they	yes	/5
sky	quit	take	girl	school	/5

Number of words read in ONE MINUTE	/50
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3. Passage Reading (PR)

Show the learner the passage chart (Chart 3).

Now I'm going to ask you to read this story out loud. If you get stuck, skip the word and keep on reading. When I say, 'Stop', stop reading the story. I will next ask you some questions about what you have just read – so try to remember the story you're reading. You will start here. (Point to the first word of the passage.)

Ready? Begin.



- Start the timer when the child starts.
- Strike a line through words that the learner reads incorrectly or cannot read at all. For example: ~~house~~
- If the learner stops for more than three (3) seconds, tell the learner to go on and strike a line through the word. For example: ~~house~~
- If the learner corrects himself/herself, accept it as correct. (If a strike has already been made on the word, circle it to mark it correct.)
- If the entire first line has strike-through lines across all the words, stop the assessment, place a bracket (]) after the last word on the first line and make a tick mark (✓) at the bottom of the exercise (in the box provided) to record that the exercise was discontinued.
- After one (1) minute, say: “**Stop**”. Place a bracket (]) after the last word that the learner has read correctly.
- Count and record the number of words that the learner read correctly.
- If the learner reads the passage in less than one (1) minute, record the time remaining on the stopwatch at the bottom of the exercise (in the box provided).

Nola plays near the house.	/5
Nola plays with the ball.	/10
Nola kicks the ball. The ball hits the window of the house.	/22
The glass breaks. Nola is scared.	/28
She runs and hides. Her father comes.	/35
He sees the glass. Her father is very mad.	/44
He told Nola not to play by the house.	/53
Nola did not listen.	/57

Number of words read in ONE MINUTE	/57
------------------------------------	-----

4. Comprehension Questions

Now I am going to ask you a few questions about the story you have just read. Try to answer the questions as best you can.



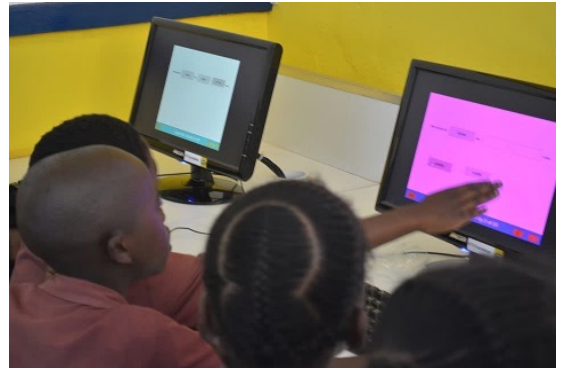
- If the child read only part of the story, only ask the questions related to the part that s/he has read. Enter a dash (--) in the boxes for questions not covered.
- Enter a tick (✓) for each question answered correctly.
- Leave a blank for each question answered incorrectly.
- If the learner corrects himself/herself, accept the answer as correct.
- Count and record the number of questions that the learner answered correctly at the bottom of the exercise.

Question	Answer(s)	Correct
1. Who was playing with the ball?	Nola	<input type="checkbox"/>
2. Where was she playing?	Near the house	<input type="checkbox"/>
3. What happened to the window?	The window was broken	<input type="checkbox"/>
4. Why did Nola hide?	She was scared. No, because the window was broken	<input type="checkbox"/>
5. Did the story have a happy ending? Why?	No, because her father was angry. No, because Nola was hiding.	<input type="checkbox"/>

Number of correct answers	/5
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End of assessment. Make sure you have properly recorded all information on each page of the assessment before letting the child go. Once everything is properly recorded and complete, thank the child and give him/her a pencil as a token of appreciation.

Appendix E: Images of BFI in Use



Appendix F: Narrative summaries of the Fidelity to Implementation Scaling

Boiketlo:

This school showed the least promise of those visited. While the program was successfully installed and updated for grade 1, they explicitly stated that they had not been using the program because of a lack of headphones. This was the school that the TOT instrument was piloted in 2014. However, there was no evidence of continued use after the 2014 visit. The teachers also mentioned that the last time they had a visit from Molteno was during the summer of 2014, indicating no ongoing monitoring efforts. This school was dropped from the research and no data was collected during the 2016 follow-up period.

Bombeleni:

This school showed strong potential and was very committed to the program. The principal was well informed of the project, and she was able to produce a timetable of BFI implementation. In addition, the school consisted of 2 working computer labs with the program successfully installed and updated for each grade level. Teachers supervised their students' engagement with the curriculum and were able to provide constructive feedback about the content of the lessons. This was the only school that confirmed continued use of the software beyond the 2015 implementation period.

Fholovhodwe:

This school showed strong promise and expressed commitment to the program. They had very limited working computers, with only five functioning machines at the one year follow period. BFI was installed and functioning, and the school procured their own functioning headphones. The computer technician was able to present a completed time on task log. The one drawback was that since there was a computer technician responsible for the lab, none of the teachers were able to discuss their direct impact from the program as they just dropped kids off at the lab and left.

Mauluma:

This school showed strong potential. The principal was occupied during our visit so we were not able to engage with him. The computer lab was operational and there was a dedicated staff delivering the program. The teachers gave positive feedback about the program and the installation was working well. No mention of TOT instrument.

Mponegele:

This school showed moderate potential. The principal was informed of program. Teacher interviews revealed some use of lessons, but not complete. Timetable was not specific to BFI, but followed EFAL/HL schedule on CAPS timetable. No TOT

documents presented. Computers were better than other schools, but recent break in halted use of the intervention. Could not verify install, but Polokwane office confirmed installations.

Samson Shiviti:

This school showed strong potential. The principal was very well organized and the laptops showed that software updates had been installed just after a week of the previous visit. Teachers gave positive feedback about the program, but no timetable could be produced.

Appendix G: Time on Task Instrument

Learner Last Name: _____ Learner First Name: _____
 Grade: Male Female Age: _____

Date	Language	Lesson(s) Attempted										Controls Mouse?		Paired?				
		46	47	48	49	50	51	52	53	54	55	Y	N		Y	N		
	<input type="checkbox"/> English <input type="checkbox"/> Sepedi <input type="checkbox"/> Xitsonga <input type="checkbox"/> Tshivenda	First Half	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Y	<input type="checkbox"/> N	<input type="checkbox"/> Y	<input type="checkbox"/> N	
		Second Half	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Y	<input type="checkbox"/> N	<input type="checkbox"/> Y	<input type="checkbox"/> N
	<input type="checkbox"/> English <input type="checkbox"/> Sepedi <input type="checkbox"/> Xitsonga <input type="checkbox"/> Tshivenda	First Half	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Y	<input type="checkbox"/> N	<input type="checkbox"/> Y	<input type="checkbox"/> N
		Second Half	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Write last activity completed:	<input type="checkbox"/> Y	<input type="checkbox"/> N	<input type="checkbox"/> Y	<input type="checkbox"/> N

Appendix H: Summaries of Classroom Observations

Observation Date: 4 May 2014

Observation School: Mogologolo Junior Secondary School (Quintile 1)

Grade(s)/Class(es) Observed: Grade 2, Class A – 10 learners

Observation type: PC (aged, running windows 2000)

Personnel Observing: Molteno BFI Staff (1)

The school had confused the date of this visit and was expecting us the previous day. However, the principal received us warmly and showed us the computer lab, which at the time of arrival was crowded with a full class of learners (+/- 40), who were using six computers to play solitaire. The principal and teacher explained that they thought it was important for the learners to be exposed to technology, but that they had no learning programs and were not quite sure what to do beyond giving learners access.

This was the first use of the BFI program for the ten learners observed, as the program was installed that morning. The learners demonstrated an immediate familiarity with computers and did not need instruction on using the mouse or drag-and-drop, so were instructed by the teacher to proceed to the first lesson (lesson 31) in Sepedi. The actual lesson content, however, posed a challenge. Some learners emerged as dominant and “took over” the lesson, manipulating the mouse and answering questions while their partner only watched. This situation was observed in three out of the five pairs, one mixed-gender and two pairs of two boys. In the mixed gender situation the girl was dominant. In the remaining two pairs, learners were observed switching places and sharing control of the mouse (two pairs of girls) at various points in the lesson, and the “spectator” could often be seen pointing to the screen and encouraging the “clicker” to perform a specified action. No pairs completed the lesson within the time frame, and errors and repeated exercises were frequent.

The teacher left the classroom to resume teaching the other learners in her class and could not be observed beyond the opening instructions to turn on the computer and click on the BFI icon. A desk was provided in the room for teachers to use when the whole class is present in the lab, which was covered with attendance registers and workbooks on the day of the visit. Evidence suggests learners are largely left to themselves to engage devices in this school. Teachers were not able to talk about the content or storyline of BFI because the program had only been installed on the day of the visit.

Observation Date: 20 June 2014

Observation School: Samson Shiviti Junior Secondary School (Quintile 1)

Grade(s)/Class(es) Observed: Grade 3, Class A – 36 learners

Observation type: PC (laptop)

Personnel Observing: Molteno BFI Staff (2) and Limpopo Premier's Office Representatives

The school was prepared in advance for the visit and knew that the Premier's Office would also be attending. The principal of this school is very organized and the lab was already set up for observations when we arrived; learners were called after. The lab is set up with rows of desks, and two learners sit per desk with one computer (laptop). The computers do not have a mouse, so learners must manipulate the pointer using a touch pad. This created some difficulty in some exercises, especially in the "drag and drop" exercises and the balloon game, as some learners struggled with the fine motor skills necessary for these tasks. One pair was observed "tag teaming", with one learner manipulating the "click" and the other swiping the touch pad to move the pointer. This strategy was ultimately not very successful, as the coordinated timing necessary for success was beyond the team. For the most part, pairs engaged with one learner manipulating the clicker and the other participating through pointing, providing answers or occasionally taking control of the touch pad. Three learners were observed not engaging; one laid her head on the desk and the other two appeared to be looking out of windows and staring into space. Partners made no attempt to engage these learners. For the most part, learners completed the lesson in 30 to 40 minutes with few errors; however, it is probably that due to the importance of the Premier's visit they had been prepped and had gone through the lesson before the observation.

The teacher began the lesson by helping the learners to turn on the computers; many pre-empted her, indicating basic familiarity with the laptops. The teacher instructed the learners to select "Xitsonga" and instructed the learners to go through the introduction lesson, which teaches point and click, drag and drop and so forth. Learners were able to go through this introduction quickly and the teacher indicated they had done it before, but there was a technical glitch which caused the directions for this section to be presented in English. Afterwards, the teacher told the learners to commence with lesson 32 (the second lesson in the program). This indicates that although the program is set up for learners to pace themselves and to have a choice of language, the teacher was not particularly comfortable with this element and preferred to mandate to the learners. The teacher also did not understand how to adjust the volume on the laptops; Molteno staff showed her and this improved the conditions of the classroom significantly. Learners did not seem distracted by the sound from other computers in general, however, it was more for the comfort of the teacher and the observers. Teachers indicated that they were very impressed with the program and anticipated that it would help their learners, especially with phonics. Teachers did not seem to prepare themselves for the PC lessons by going through them and could not identify the content of the next lesson or any other lesson, and reported that they have not yet started using the teacher guide activities or exercises.

Observation Date: 19 August 2014
Observation School: Masungulo 2 Junior Secondary School
Grade(s)/Class(es) Observed: Grade 2 – 10 learners
Observation type: PC (new)
Personnel Observing: Molteno BFI Staff (2)

This is a small school with only one class per grade. About one-third of the grade 2 learners were observed using the BFI program. The lesson observed was the third lesson of the grade 3 program (lesson 34). The teacher explained that this was the third time for these learners to use the program, but that lesson 32 did not work properly in Xitsonga. The teacher said they had not done either of those lessons in the computer lab as the whole class would not fit and they had no sound in the lab (no speakers); rather they went through the lesson on her personal laptop in the classroom.

Learners were provided with shared headphones to go through the lesson. All ten learners were very excited to be using the computer; one pair had a fight over the mouse which led the teacher to instruct all the learners to switch back and forth between each exercise. Given this directive, the learners shared fairly equitably, although there was another squabble regarding what to do with a wrong answer and if the learner had to give up the mouse at that point or could try again. The teacher instructed them that any attempt counted as a “turn” and things settled down. Learners were able to complete most activities but struggled with the grammar and sentence building. Learners also struggled with the fine motor skills required for drag-and-drop and clicking the balloons in order in the final activity. These took multiple attempts for all the pairs. At the comprehension passage, all the pairs read out loud in tandem from the beginning to the end, which likely indicates that they have no experience with independent reading. However, most pairs were able to answer the comprehension questions correctly. The learners seemed to enjoy typing and the balloon game; however, when asked they told the teacher they liked learning phonics the best. Beyond this interaction, telling a pair who finished early to proceed to the next lesson, and clearing up the discipline in the beginning, the teacher provided no instruction. However, it would have been difficult for her to, as the learners were wearing headphones. She said that they did not follow up with writing activities yet, as the learners were not yet “ready to write”. She also said they had lost their teacher guides and were given a new copy.

Observation Date: 20 August 2014
Observation School: Banana Junior Secondary School (Quintile 1)
Grade(s)/Class(es) Observed: Grade 3, Class B – all learners
Observation type: PC (1 for the whole class)
Personnel Observing: Molteno BFI Staff (1)

This school has been using the BFI Program intermittently, and is one of the more faithful implementers. However, it is currently hindered by very aggressive viruses in most of its computers, and the fact that nine of its computers were donated by another NGO and could not be used for the BFI Program. This was later resolved through conversations with the circuit manager and the competing NGO. Another problem the school faces is a lack of speakers and headphones; the computers which are working cannot at present be used for the program due to lack of sound. The principal is working to raise funds for additional speakers, but at present they have only one set.

The lesson observed was the grade 3 level fourth lesson (lesson 49), in Xitsonga. There were no technical glitches in this lesson. The school strategy was to have a teacher “lead” the students through the lesson, with the teacher controlling the mouse and the learners (22) crowding around the computer to watch. The teacher showed them how to hold and manipulate the mouse, but no learners were given an opportunity to try this or to personally complete any of the activities. The class moved through the lesson en masse, with the teacher clicking from one activity to the next and prompting vocal responses from the learners before selecting answers or completing activities.

This strategy worked fairly well for some activities: the key word and key sentence, punctuation, conjunction, and comprehension exercises in particular. Other activities were compromised, such as the sentence building, word building, typing and grammar activities. These would have been more effective if the learners had taken it in turns to try them. Additionally, as the teacher guided the learners through the activity, she precluded any mistakes, so the answers (except one grammar activity) were all correct and the learners were able to move swiftly through the lesson with very few repeated activities. Ultimately, although this approach was the most feasible for the school at the time, it disallowed the language selection, self-pacing and feedback aspects of the program. The learners themselves seemed engaged and eager to learn despite the situation, and were interested in the computer. After the lesson, two learners were seen playing with the mouse of another computer which was switched off. The principal indicated that he was working on getting more speakers so learners could try working with the computers themselves, but the teacher engaged in the lesson was positive, saying that the explanations given in the program were better than those she herself gave and that she thought the learners gained a lot from working with the program in this way. The teacher showed that she had prepared by going through the program. She was able to talk about the characters and the story for both that lesson and the next lesson, and told us of two technical glitches in the grade 3 she had encountered. However, she said they did not use the teacher guide writing activities for grade 3 because they did not have time and needed to complete workbook exercises instead.

Observation Date: 22 August 2014

Observation School: Jim Tshivonelo Junior Secondary School

Grade(s)/Class(es) Observed: Grade 2 – 30 learners; Grade 3 – 30 learners

Observation type: tablet

Personnel Observing: Molteno BFI Staff (2)

Originally this was intended to be a PC observation; however few of the PCs were working properly (they had only 6 working to begin with and three had malfunctioned in the interim). So accommodation was made to make this a tablet school and the tablets were introduced to teachers and learners. Learners were very excited to be working with the tablets; teachers indicated the learners were more excited for the tablets than the computers. The tablets were used in the classroom with the teacher and the computer teacher (hired by the School Governing Body). The computer teacher was very knowledgeable about the program and gave the staff a list of errors encountered in the Tshivenda version of the program. Learners had been working in small groups in the lab with the program, but the teacher did not have a record of what lessons were completed by which learners and only knew they were at different stages of the program.

Grade 2:

Learners working in pairs were allowed to choose their lesson and language; all learners selected Tshivenda but different lessons. It seemed the learners could not remember which lessons they had done before. Learners had less trouble with the tablet than the mouse or touchpad, overall, with the exception that learners had a tendency to accidentally press the “home” button with the palms of their hands as they tried to move a word or letter on the screen. Additionally, the drag and drop still presented some challenges and these activities often required more than one attempt, especially at the beginning of the lesson. Some activities such as the balloon game required a lot of precision to pop the balloons and this resulted in errors as learners would press in the correct places in the correct order, but errors would occur due to the program not registering the “pop” correctly. Learners did not seem particularly frustrated by this, surprisingly. Perhaps due to the structure of the tablet platform, both learners manipulated the device at various points without any formal handover or turn-taking. This led in some pairs to an obviously dominant learner doing most of the activities as their comprehension or ability was quicker than that of their partner. Areas of particular difficulty seemed to be the phonemic awareness and grammar activities; learners had little difficulty with comprehension or forming words and sentences. Learners did not finish the lesson within the allocated 45 minutes, but were allowed extra time. The teachers walked around supporting and encouraging pairs throughout the lesson, which seemed to increase the excitement of a successfully completed activity.

Grade 3:

The fine motor skills of the grade 3 learners were higher than that of the grade 2 learners and they had little difficulty with drag and drop, although the balloon game remained a challenge. The settings of that activity need to be changed so the balloons are more spaced and there is a larger “correct” register area around each balloon.³ Learners in grade 3 were also challenged by the grammar and phonemic awareness activities, but only at first; they caught on quickly to the idea of “same sounds” and parts of speech. The teachers also participated in the grade 3 lesson by walking around and encouraging learners, and by helping with technical difficulties. They stopped this class early in to give instructions on how the learners should hold their fingers to avoid accidentally exiting the program. They still exited quite frequently and this required a complete restart of the lesson if they had pressed the “back” function on the tablet. If possible the program should be able to “lock” open to avoid this.⁴

Teachers interviewed were positive about the program and the impact it would have on the literacy levels of their learners. One teacher mentioned that it was exciting to see a program in the Venda language, which she had not seen before. The principal thanked us for the tablets and promised to seek funding to purchase some for the school on her own.⁵

Observation Date: 26 February 2015
Observation School: Ninakhulu Primary School
Classes observed: Grade 2A, B and C
Observation type: PC
Personnel observing: Molteno BFI Staff (2)

The principal welcomed us and informed us that the learners are comfortable with the program as they have been using it. She then led us to the computer lab where we found a grade 3 teacher teaching BFI to grade 3 learners. As we approached, she instructed the learners to open the BFISA folder on their desktops. The learners did not seem to be familiar with the program as they had difficulties in accessing it.

Soon the HOD of the foundation phase brought in a group of grade 2 learners from the 3 grade 2 classes that the Molteno staff has randomly selected. The learners worked in pairs. The excitement of the learners showed that they have never used the program, also they were not familiar with it as they had to be assisted in every step of the lesson and activities, as the result they were not cooperative and none

³ This was subsequently revised in the manner indicated here.

⁴ This is not possible; the function is limited by Android according to our development team.

⁵ She succeeded; the school now has 40 tablets of its own loaded with the BFI programme and King of Maths.

could finish a lesson. One of the grade 2 teachers indicated that the learners were using the program for the first time.

Date of Observation: May 2015

Observation School: Mogologolo Junior Secondary School

Grade: 2

Observation type: tablets

Personnel observing: Molteno BFI staff (2)

In addition, we also observed Mogologolo Primary School, originally a member of the control group, they received a grant from UNESCO and received 50 tablets with Bridges to the Future installed for grades 2 and 3. We were able to observe one of the second-grade classes being introduced to the BFI tablets. 50 Students were grouped in tables of 4-6 students with one tablet per group. The teacher, who had already familiarized herself with the program, instructed the class on how to turn on and access the program, navigating around the room and helping the students. The groups then went onto lesson one and advanced at their own pace with the teacher circulating the room, helping groups when needed. For the most part, students stayed on BFI, however there were instances when groups would be on Angry Birds or another game. In addition, select individual students would roam around the class or switch groups and would not give 100% attention to the BFI program. Even though tablets allow for greater interaction among the students, and even though students were familiar with navigating the tablet, in many groups, only one or two students would take on an active role with the rest being passive, highlighting the need for smaller groups when implementing BFI. The students were on BFI programs for an hour straight, with no breaks in between. In our opinion, it would have been valuable for the teacher to guide the class together through the first less and bridge the tablet technology with more traditional pedagogical instruction in order to keep students engaged and on task. Our recommendations are for BFI to be implemented with students in smaller groups and more structure in blending traditional pedagogical instruction and technological innovation.

Observation Date: May 2015

Observation School: Mogologolo Junior Secondary School (Quintile 1)

Grade Observed: Grade 2, Class A – 50 learners

Observation type: Tablet

Personnel Observing: Molteno BFI Staff (2)

Learners were grouped in groups of 4 – six sharing one tablet with one teacher moving around the individual groups, assisting and checking the progress. Some were able to switch on the tablets and access the BFI program while others needed the teacher to assist them. Each group had a group leader. The learners were comfortable in using the tablets and familiar with the BFI program in such a way that they were able to go back to the home screen and restart the program when an

activity froze. As the teacher was moving around, when she picks up a common error or difficulty she would stop the learners and clarify whatever that needed to be clarified. The learners were engaging with each other as groups would ask assistant from another group if they are stuck while the teacher was busy with others. Groups moved on their own pace, they were not doing the same lesson/activity at once. As the result at the end of session which was an hour long, some groups were in in the first four lessons while one group was on lesson 12.

Observation Date: 3 June 2015

Start Time: 10:21am (55 minutes)

Observation School: Sansom Shiviti School

Grade(s)/Class(es) Observed: Grade 2, Class A – 37 learners

Observation type: PC (Netbook Laptops)

Personnel Observing: ILI Staff (1)

It took the teacher about 15 minutes to get the laptops powered up and students situated around desks. Machines didn't have any headphones and the learners were paired up 2 and 3 students to a laptop. However, the volume and functioning with the small groups didn't seem to be compromised at outset. Some of the laptops weren't working due to a flat battery and the teacher had to leave the room to fetch an extension plug. While this is a clear sign of use, care should be taken to make sure the devices are properly charged before use.

At 20 minutes in, the learners are just getting to the story. Several of learner groups were patiently waiting at the home screen either because they did not know how to progress to a lesson, or they possibly because of previous instruction to wait for the teacher to begin. A majority of the learner could not open the program on their own, so the former explanation may have been more accurate. Other complications with use included the use of the track pad and double clicking. This was also apparent during the pilot testing phase.

Learners primarily select home language. While the teacher is constantly circulating, she is primarily troubleshooting malfunctioning laptops rather than ensuring time on task with the software. At 32 minutes in, some learners are still sitting at the home screen, although further observation revealed that this was due to frequent crashing of the software. Upon inspection, I confirmed that the update had been installed with grade 1 lessons.

At 40 minutes in, all learners have now been able to begin a lesson. Generally, in groups of 3, the center student controls the lesson, while the other two passively sit and observe. However, several passive learners are involved and constantly pointing at the screen and helping with answers. At 50 minutes in, I began to circulate to check progression through the lesson. The activity list was truncated on these devices so it was hard to see at what part of the lesson the learners were on.

Although, many seem to still be in the single digits. At 11:15 I completed the observation and left the room, but the teacher remained to work with the learners.

While it is understandable to put students in larger groups when introducing the tablets, it also underscores the need for a maximum of two students per tablet when actually implementing the program in order to maximize time on task for students. Furthermore, I would have liked to see a more blended learning approach, with the teacher using group mini lessons to break up the hour-long introduction to the tablet and program.

Observation Date: 4 June 2015

Start Time: 11:30pm (50 minutes)

Observation School: Mogologolo

Grade(s)/Class(es) Observed: Grade 3, Class A – 45 learners

Observation type: Tablets

Personnel Observing: ILI Staff (1), Molteno enumerator (1)

At 11:30 am the lesson begins. The teacher begins by giving instructions to the learners to power on the devices, the learners are sharing headphones that come included in the tablet boxes. 2 learners to a tablet, but I was told that normally they each only use one tablet. This is a very efficient start, it appears that the learners are comfortable with the technology.

Within 5 minutes all the learners are working on the BFI program. There are some noticeable struggles with clicking and dragging operation from the students. The teacher is circulating and assisting the struggling learners. There are 7 units not charged and the teacher has to leave the room to find an extension plug. This could be a possible indication of use, but attention to charging will be important. However, even with the teacher out of the room, the learners that have functioning tablets are still focused on the program.

The typing activity on the tablets appears to be working well. Some learners start to overlook with other groups. The learners with dead tablets are now circulating and looking on with other learners. Upon circulation, I start to notice that some groups are working on other applications.

20 minutes in, the teacher announces something to the learners and several students jump and run the front of the room to do an activity on the board while other continue working on their tablets. Apparently, the teacher has asked them to come and write vocabulary words that they have learned in their lessons. Breaking focus like this may have an impact on time on task, but it is nice to see the teacher engaged in the lesson beyond trouble shooting. Most of the students are working in home language and have advanced through the middle teens of the program by 25 minutes in. The paired groups appear to be working well with regard to

active/passive learning. There appears to be some bickering about who is actively working on the program.

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