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Supporting Home Language Reading through Technology in Rural South Africa

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Abstract

This paper describes a short-term longitudinal study in South Africa, with children in grades 1-3, some of whom received a multimedia technology reading support program in one of three home languages and English (through existing computer labs in schools). Findings reveal a positive and significant impact on local language reading acquisition among children with multimedia support. The study shows that effective literacy support can help struggling rural learners make significant gains that will help them complete their schooling. The ability to accomplish a full cycle of primary school with fully developed reading skills has significant implications for life-long learning.

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1. Introduction

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).

An unintended consequence of universal primary education has placed new constraints on education systems and their ability to deliver quality learning environments (Wagner 2018). 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). In September 2015, the United Nations ratified 17 Sustainable Development Goals (SDGs), including a central goal to improve education quality (Goal 4) and attain universal literacy (United Nations 2015).

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 second 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. In these contexts, teachers are often inadequately prepared to respond to such diversity in learner needs (Ball et al. 2014).

Literacy programs incorporating learning and teaching support materials (LTSM) is highly dependent on how well the resources are utilized by teachers and language of materials offered (Glewwe et al. 2009). Comprehensive and structured programs including training and support in the use of digital LTSM resources have proven effective (Piper et at. 2014) as well as with local language adaptations (Piper et al. 2016).

To date, South Africa has deployed a few notable research projects emphasizing learning and teaching support. In 2009, the Structured Method for Reading Success was associated with positive and significant gains in correct letters read per minute among 29 treatment schools across three provinces (Piper). In 2010, the Gauteng Primary Literacy and Mathematics Strategy

attempted to scale a structured LTSM program through instructional coaching (Fleisch et al. 2016). The Early Grade Reading Study (EGRS) expanded this LTSM model by investigating the effects of three distinct strategies: centralized training, school-based coaching, or community-based parental coaching. After one year of intervention, midline results indicated small to moderate effects from the first two coaching strategies with small to negligible effects of the parental coaching strategy (DBE 2017). While these interventions were associated with positive outcomes, they each emphasized support to teachers through lesson planning and coaching instead of reading support material designed specifically for student learning.

Despite initial success with LTSM programs, local language instruction remains a serious challenge for ensuring quality learning environments among South African students in multilingual settings (Moloi & Chetty 2010). For many students, simple grade-appropriate learning material developed in their home language is unavailable. Equally important for improving literacy is developing resources that actively engage learners and aligns with contexts that are culturally relevant to them. As part of the global effort to achieve Goal 4 of the SDGs, the UN and other funding agencies see technology as a major enabling tool. To date, little evidence exists concerning major claims about the success of particular interventions, especially in developing countries. However, increased experimentation with digital literacy programs designed for students and incorporating locally produced reading materials is delivering promising results (Ridell 2001; Aderinoye & Rogers 2005; Wagner et al. 2010).

Distinct advantages of information and communication technologies (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). Bulman and Fairlie (2015) find evidence of positive effects among guided ICT interventions are strongest in developing countries due to their ability to substitute for lower-quality instruction. However, despite increases in investment (WITSA 2010) and coverage (ITU 2015) serious challenges remain in understanding uses of technology for enhancing learning outcomes. Much of the challenge is related to the design and purpose through which technology enabled interventions are deployed.

Wagner et al. (2014) was one of the first reviews to conceptualize an effectiveness framework for improving ICT program development and implementation for education planning. Within this framework, a set of defined intervention purposes overlap with appropriate technologies and intended end-users to develop a design solution approach. As purposes or combinations of purposes intersect with intended end-users and appropriate devices, a variety of program designs can be developed.

Guided instruction implies the use of specific software carefully aligned to the curriculum along a prescribed schedule (Arias-Ortiz & Cristia 2014). 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 not replicated once the combined effects of the hybrid model were separated into distinct experiments (Linden 2008). A follow up study also found significant depreciation in the intervention effect on achievement in subsequent years (Linden 2008).

Kam et al. (2009) tested the impact of cellphone-based learning on literacy achievement through an afterschool program in India. While literacy improved overall, the authors found stronger gains among the learners that scored higher at baseline and thus better equipped to take advantage of the opportunity (2009). Another study introduced adaptive lab-based learning software across a sample of schools in Ecuador to complement classroom instruction. 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). Research in China found similar results where positive and significant impacts were observed in math but not in 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.

Despite this growing body of evidence, serious 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 as differences across initial achievement. 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 low-literacy rates prove that more research is needed to explore how children learn to read and how teachers, institutions, and technology can help.

The present research extends previous literature by investigating whether access to contextualized, digital reading content in their language of choice can improve early reading outcomes among foundation phase learners. Underpinning the design of the program is the integration of technology to provide reading support material that directly builds upon the students' language and cognitive competencies. This study fits into a perspective that views learning as a cumulative lifelong process (Wagner 2018).

2. Overview of the Intervention

The present study was carried out in collaboration with a local implementing partner in the northern province of Limpopo, South Africa with support from the South African Department of Basic Education. The study was administered in computer labs among participating government primary schools. The goal was to investigate the impact on developing early reading skills in low performing rural schools, among historically disadvantaged children. A total of six treatment

schools offering instruction in one of the province's three prominent local or *home* languages[1] were selected to participate while an additional eleven schools were selected as a comparison group.

Treatment schools were asked to take "foundation phase" learners to the computer labs once a week on average.[2] Each session ran for one period during the school day for 45-minutes under teacher supervision. The intervention took place from mid-2014 to mid-2015. Data collection took place over one full calendar, spanning two academic years. A one-year follow-up was conducted one year later in 2016 after the formal intervention had ended.

The Bridges to the Future Initiative (BFI) is designed as a multi-lingual, culturally appropriate, phonics-based approach to support early literacy instruction. The software incorporates interactive activities to reinforce letter-sound recognition, phonemic awareness, as well as sentence construction and whole-text reading. Working in three local 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.

2.1 Content Development

A team of African language experts, local education specialists and software designers assisted in the development of the program content to ensure linguistic accuracy and contextual relevance. The process for BFI content development began with an English draft of a storyline that was incorporated into an introductory audio-visual element for each lesson. Foundation phase language teachers then adapted the content as necessary before it was reviewed for accuracy by local language editors. Each lesson incorporated activities and prompts related to these introductory audio-visual components.

Literacy experts from the local partnering organization reviewed each of the reading passages that were incorporated into the end of the lessons. For the English passages, a readability score was applied to ensure both appropriateness and developmental difficulty. Overall word count, average words per sentence, and developer and editor comments were used to determine difficulty level. Professional translators and language editors reviewed each of the passage drafts commenting on the linguistic accuracy, overall flow of the language, appropriateness of the story or content to the respective grade levels, and quality of presentation.

Preliminary versions of the content were field tested prior to installation and full rollout. Project staff conducted formative evaluation tasks among five non-participating schools related to content quality, technical functionality, and software glitches. The program was installed

[1] The South African Department of Basic Education prefers the term "home" language to replace the internationally used terms of local or mother-tongue language (DBE 2013).

[2] Foundation phase learners are students in grades one through three.

across treatment schools only after a final satisfactory review of the digital content was completed.

2.2. Lesson Design

The BFI lessons were designed to complement the reading curriculum taught in the classrooms. The content was contextualized visually and thematically to the realities that the learners experienced in their daily lives. Each lesson followed a similar structure that began with an animated story line and continued with a set of activities related to the content in the story. The number of the activities varied by level of the lesson and increased in complexity as the lessons progressed. Specifically, the activities emphasized the following literacy skills:

- Phonemic awareness
- Listening (key sentences)
- Sentence construction
- Typing and spelling
- Grammar and punctuation
- Short passage reading and comprehension

The lesson design was intended to be intuitive and engaging for the learners. Each lesson included animations, games, and an immediate feedback protocol to reward correct answers while reinforcing key information when incorrect answers were selected.

The software was originally developed for use in adult learning centers in South Africa (as described further below). Subsequently, the software was adapted from the adult version of the program so that it could be utilized for young learners in primary school, which had become a government priority. As part of this process, the team drew from local knowledge to develop contextually accurate story lines and audio-visual content that children could relate to from their own lives.

3. Research Design

3.1 Data Collection

The local implementing partner led the program development component and was responsible for data collection under the advisement as external researchers. A local team of enumerators fluent in each of the home languages was hired at each wave of data collection. Classroom teachers were responsible for administering the intervention with monitoring support from the implementing partner. Both the enumerators and classroom teachers received orientations to the program and were trained on data collection and proctoring of the computer lab sessions, respectively. The research team continued to advise the implementing partner staff through regular conference calls and annual site visits.

The BFI software was designed to complement classroom instruction through self-paced and integrated learning. All learners in the study received the normal literacy instruction mandated through the national South African Curriculum and Assessment Policy Statement. The primary method of assessment incorporated a repeated measures design using an adapted version of the Early Grade Reading Assessment (EGRA) (RTI International 2009; Gove & Wetterberg 2011). EGRA is widely used in developing countries as a means of assessing progress along a set of critical early reading skills for primary school learners.

In addition to the EGRA data, enumerators collected data on individual demographics including age, gender, language use at home, and year in school. Learners were assessed at each wave of data collection regardless of their advancement to the subsequent grade level. The emphasis of the data collection efforts was to follow the same learners over time for longitudinal analysis.

At each EGRA administration, learners were assessed on individual reading skills along four general components: letter sound recognition, familiar word reading, oral reading fluency (ORF), and reading comprehension. At baseline, enumerators administered individual EGRA assessments in one of three local languages. In waves two and three, English language was added to the data collection efforts. Enumerators did not collect English language data at baseline because learners did not have sufficient language skills to complete the assessments in grade one. Difference scores on each of the EGRA components were the outcome measures of interest for this study.[3]

3.2. Sampling

In total, six treatment schools and eleven control schools receiving non-guided digital content were included in the evaluation. Of the six treatment schools, one of the sites was dropped due to non-compliance with the program. The non-compliance was due to a lack of headphones available to run the program in the computer labs.[4] A total of 215 learners were tracked from baseline to endline.[5] These 215 learners were aged 7 to 11 years and were registered in grades 1 through 4. In terms of gender, there were roughly 53% and 51% females for the control and treatment groups, respectively.

There are three home languages spoken throughout the region where this study took place. Within this sample, the majority of students came from Xitsonga speaking regions (39%) while roughly 32% were from Sepedi speakers and about 29% were Tshivenda speakers. For this study, home languages were combined into a single variable due to the limited sampling by

[3] These measure the difference in EGRA component score from the learner's previous score.

[4] Additionally, one of the control schools was dropped because only one student was successfully tracked at both time points.

[5] We initially anticipated a randomized controlled trial with stratified random sampling at the school level. However, the randomization revealed heterogeneity between treatment groups at baseline. Therefore, we applied the indicated adjustments in our analysis to correct for baseline differences.

language. However, we also present results disaggregated by specific language group for illustrative purposes.

Since this intervention was developed for the lowest performing schools in the Limpopo region, we included quintile scores to determine differences in impact by performance group. Within this sample, roughly 37% of the learners came from low performing schools (tier 3), 41% were from lower performing (tier 4), while roughly 22% were from lowest performing schools (tier 5). Summary statistics of the demographic data are provided in Table 1 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

Table 1 Summary Statistics of the Longitudinal Data

4. Results

To determine the impact of the BFI treatment on early reading outcomes, we estimated difference scores with clustered standard errors between the intervention time points (baseline vs. endline).[6] Controls for gender, grade level, and school quintile were included in the regression models.

[6] See Castillo (2017) for further detail regarding statistical models and instrument validation.

Figure 1 illustrates the individual gain scores across all EGRA components in year 2. BFI had positive and statistically significant effects on the higher order reading skills, namely: mother tongue oral reading fluency (measured as correct words per minute, or CWPM) and reading comprehension. There were no significant differences between groups for letter sound fluency or familiar word reading. Stars indicate statistically significant differences at the $p < 0.01$ level.

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 interpreted as an improvement in a learners' ability to read by almost eight CWPM over the control group. This value represents nearly three-quarters of a year of additional reading growth when compared to reading growth from control schools within this sample.

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 interpreted as learners being able to comprehend and recall twice as much of the content they read compared to the control group (as measured by proportion answered correct on the EGRA reading comprehension component).

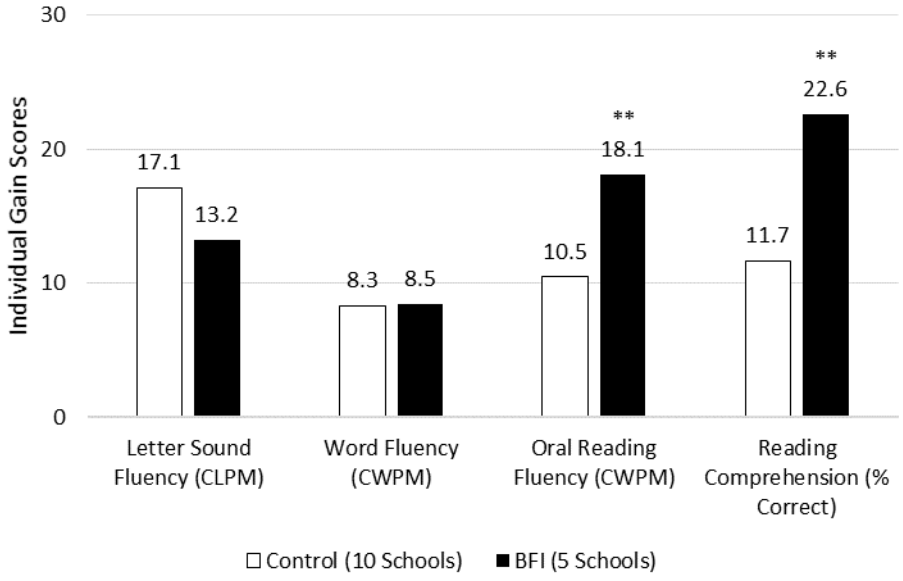

Fig. 1 Individual Gain Scores by EGRA Component and Treatment Group, Year 2
Note: Stars signify statistically significant differences at the $p < 0.01$ level

Figures 2 and 3 illustrate the repeated measures scores on the ORF and reading comprehension gain scores, respectively. Tables 5 and 6 provide the standard deviations by treatment group.

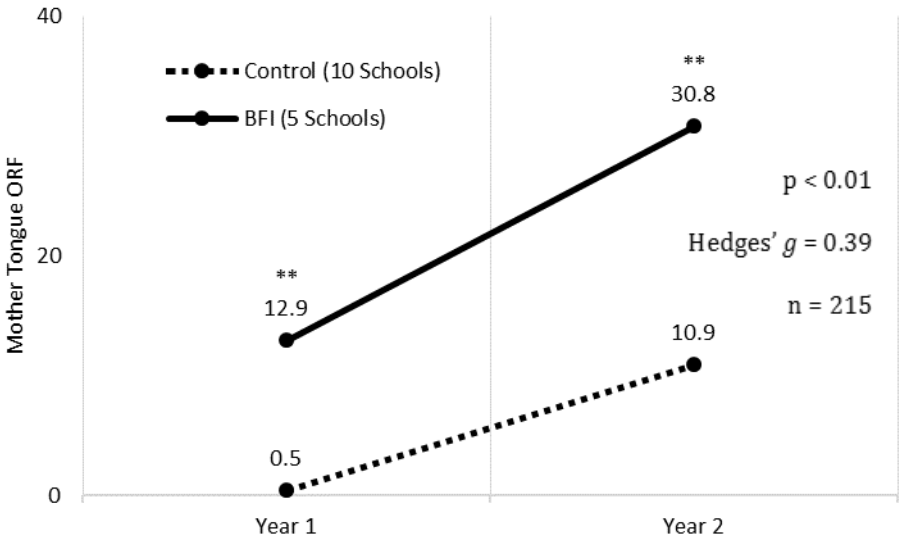

Fig. 2 Repeated Home Language ORF Scores by Treatment Group
Note*:* Stars signify statistically significant differences at the p < 0.01 level

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

Table 2 ORF Pre and Post Assessment Standard Deviations by Treatment Group

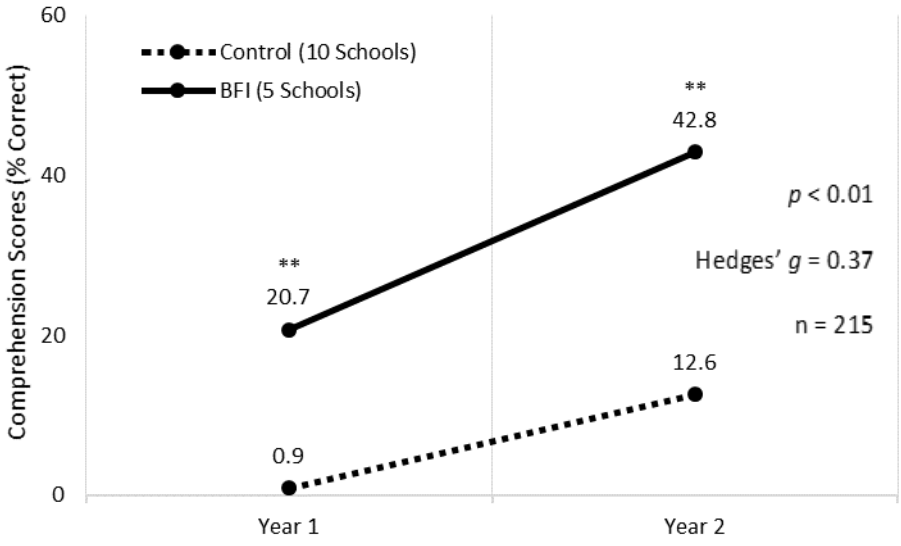

Fig. 3 Repeated Measures Home Language Comprehension Scores by Group
Note*:* Stars signify statistically significant differences at the p < 0.01 level

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

Table 3 Comprehension Pre and Post Assessment Standard Deviations by Treatment Group

In addition to the main treatment effect on literacy outcomes, females also demonstrated significantly greater ORF gain scores than their male counterparts within this sample. However, grade level and school quintile were not significantly different between groups on ORF gain score outcomes.

To further explore the relationship across languages, Figure 4 presents the reading outcomes broken out by distinct home 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 size across languages.

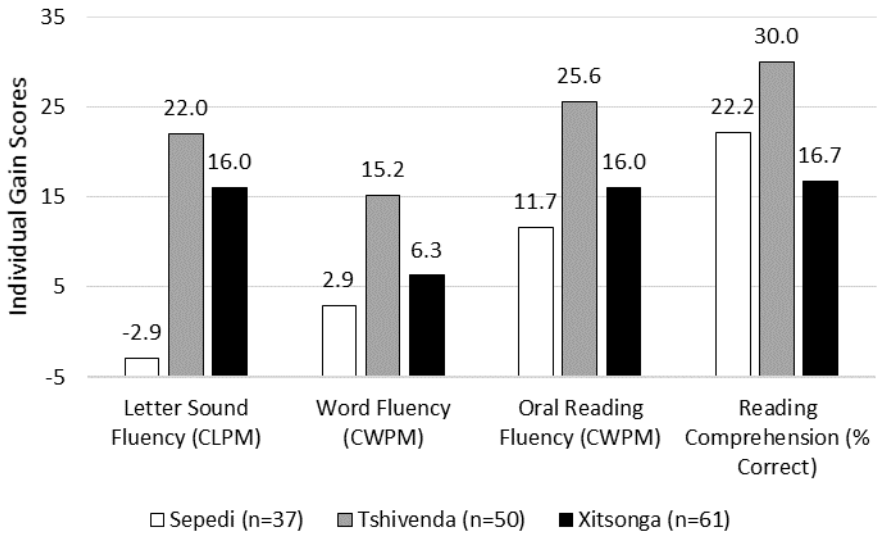

Fig. 4 Individual Gain Scores by EGRA Component and Mother Tongue for the Treatment Group, Year 2

Repeated measures design assumes that individual's scores at each wave of data collection are correlated with each other. It is understandable that a high achieving learner at baseline will also fall within the higher end of the achievement distribution at endline assessment. Fixed

effects models are extremely robust to such dependence of repeated measurements (Allison 2009).[7]

Within the fixed effects model of individual mean scores, the BFI treatment impact remained positive and significant for oral reading fluency ($t = 2.7$; $p < 0.01$). Like the DID model, the BFI effect can be interpreted as 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 predictors within this model. As indicated, girls showed significant ORF gains over boys within the DID model. However, a test for an interaction of gender with the treatment effect within the FE model revealed no difference in the impact of the BFI intervention between boys and girls ($t = -1.63$; $p = 0.1$). BFI impact also remained positive and significant for reading comprehension within the fixed effects model ($t = 2.42$; $p < 0.05$) and interpreted as double the comprehension gains over the control group within this sample.

5. Discussion

This study improves on previous research on ICTs in support of multilingual reading in several important ways. First, research on ICT literacy interventions have largely focused either on English language content or on unguided software (Wagner 2014). The BFI study incorporates both local African languages and instructionally-guided software. Further, the software provides reading support material through a structured and remediated approach in three South African home languages and English. In addition, previous research primarily relies on cross-sectional, repeated measures design to determine program effectiveness, while the BFI study incorporates repeated measures analysis by tracking the same learners from baseline to endline and collecting literacy data in both home language and English for each student.

Findings supported the hypothesis that BFI software would improve early reading outcomes. Endline results showed 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 at, or nearly double, the gains in literacy achievement over the control group, accounting for almost a full year of reading and comprehension growth.

This study provides evidence that ICTs can support learning in developing countries when delivered through a guided-use approach that is contextualized to the realities of the end-user (Arias-Ortiz & Cristia, 2014). While control schools included in this study did not use the BFI program, learners were given access to alternative digital content through similar, school-based computer labs. The main difference between these two groups was the intentional structuring

[7] 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.

of the BFI curriculum through language-specific and grade-appropriate reading support content.

Further, even though the present research focused on young children, our previous work in South Africa and earlier work in India (Wagner, Daswani & Karnati 2010) provide considerable hope that this type of guided, digital instruction can facilitate learning across the life-span and across regions. The South African current study was previously attempted among Adult Basic Educational Training (ABET) centers within the same region from 2010-2014. This work was part of a government-sponsored South Africa adult literacy initiative (McKay 2015); RSA, 2000). With a growing population of low-literate youth and adults, a main function of the ABET centers was to improve adult reading skills. However, the lack of an effective adult curriculum with graded learning steps made it difficult for ABET trainers to support their adult learners (Dean, 2011). Therefore, an ABET version of BFI was developed and implemented in a set of centers with promising results. While not part of an experimental study, this early work on ABET produced promising results.

In India, a few years earlier, the BFI platform was implemented in after-school centers in the state of Andhra Pradesh, (Wagner, Daswani & Karnati, 2010). The research team conducted a basic skills assessment measuring reading, writing and math among out of school youth and adults (mainly adolescent girls and young women), while a simultaneous study was conducted among primary grade learners. Results were associated with strong motivation, along with modest, but empirically positive impact on reading measures among both groups – providing further evidence of the potential for technology to support learning across the lifespan (Wagner, Daswani & Karnati, 2010). Based on the present study with young learners, as well as youth and adults – each group learning in mother-tongue with a choice of multiple languages on the BFI platform – confirms the notion that there is much in common among learners of all ages who are beginning readers. Each group benefits from being able to understand in their first (preferred) language, while being offer a choice of learning in a multilingual, guided context.

6. Conclusion

Universal primary education was the emphasis of the previous generation of global development goals for learning (United Nations 2000). However, even with impressive gains in access, reading skills remain low in rural South Africa. Ensuring quality home language instruction remains a serious challenge for achieving Goal 4 of the SDGs in multilingual settings throughout the region (Moloi & Chetty 2010). Limited teacher capacity compounds deficiencies among struggling learners (DBE, 2008). The present research demonstrates that reading performance can be enhanced through well-developed and contextualized digital material in under resourced, low-income contexts among diverse learner backgrounds. Learners who were introduced to the guided BFI software produced greater gains in both oral reading fluency and reading comprehension outcomes. These findings offer further evidence of the enabling impact ICTs can have on improving education quality.

This study also offers important insights for implementation within the ICT for development research domain. One year after the conclusion of the BFI implementation, site-based observations and interviews with school administrators revealed that only two of the treatment schools continued BFI program use. Malfunctioning hardware and a delayed implementation schedule into the school year were common reasons for low fidelity to implementation.[8] This is, of course, a cautionary tale of many interventions: after the intervention is over and if support is not maintained, participants often revert to previous behaviors.

Other broad recommendations follow from this study. Formal accountability is a key factor influencing sustainability. Site visits prior to implementation revealed that while schools may have functioning computers on site, the labs were not always intended for early grade use. Therefore, ICT deployment should be accompanied by intentional accountability measures to ensure alignment along the program implementation plan. Given the expansion in technology interventions in developing countries, future research should include more extensive accountability measures to ensure consistent oversight and continuity of implementation.

One component that could have strengthened the 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 treatment 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 student monitoring.

Continuous support for the integration of the software to the classroom-based literacy curriculum is important for teachers. This study made provisions for initial training and orientation to South Africa's national reading strategy, but sustained efforts would have improved teacher capacity and implementation fidelity.

Another issue is the total cost of intervention implementation. Hardware is one oft-cited financial component of ICT projects. Yet, comprehensive training or readily available technical support for troubleshooting complications with the program are often under-budgeted or unaccounted for within ICT interventions. Very few evaluations have incorporated a cost component when assessing ICT deployment in schools, including the present study. Future research comparing variations of ICT inputs and the respective costs per unit of learning will be critical for informing the sustainable design of ICT interventions in under resourced settings.

Overall, the BFI approach to ICT-based learning contributes to the literature on learning solutions in global and diverse contexts across the lifespan. As a central mandate of the SDGs, future efforts should continue to incorporate strategies for understanding and improving learning quality among students in poorly resourced classrooms. The impact of this research

[8] For discussion of Year 3 results, see Castillo (2017).

helps explain how struggling readers can make substantive gains in their reading outcomes through improved learning environments.

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